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Resource Allocation Methodology To Support Mission Area Analysis

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The Office of the Director, Program Analysis & Evaluation (OSDPA&E), is planning to institute a Department of Defense (DoD)-wide Mission Area Analysis (MAA) program as a key element of the Planning-Programming-Budgeting System (PPBS) cycle. MAAs--broad analyses that treat the highest levels of force aggregation and provide cross-service, cross-mission perspectives-are an essential element of post-Cold War planning. MAAs, through prescribed in DoD Directive 5000.2, have yet to be defined formally within the DoD. The MAA program envisioned will examine, among other things, potential force structure and modernization trade-offs that are essential to the formulation of an affordable long-term plan for defense resource allocation.

This work described herein was to develop methods for assessing capabilities of alternative force structures for warfighting and non-warfighting missions as part of the MAA process. This methodology proposed assesses joint force structure based upon warfighting requirements. Then, using a similar methodology, assess the capabilities of that force structure analysis has often been policy driven and lacking in detailed objective analytical support. This report is an attempt to develop a methodology that will provide some analytical rigor to the process.

From now the warfighting force design process applies to an integer programming (IP) model to make force-unit trade-offs, using "Mission Capability Packages' (MCP's) as building blocks. The IP model, which may eventually evolve to a generalized mathematical program, determines efficient (i.e. non-redundant and effective) force mixes to accomplish given missions. In the model, MCP's are defined as integrated slices of the total force required to accomplish assigned missions. For example, a land combat MCP, which could have various configurations, would contain ground units, support units, lift assets for mobilization and deployment, and air assets for sustainment By considering various MCP's, an assessment of efficiencies in total force capability and cost can be ascertained.

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This resource allocation methodology presented herein was developed by Drs. John V. Farr, DSE, USMA, and Alfonso A. Diaz, OSDPA&E. MAJ Michael S. Nelson, DSE, developed the GAMS implementation of the mathematical program along with the spreadsheet interface and also aided in the writing of this report. Dr. Diaz developed the total MAA concept. Dr. Farr developed the Resource Allocation Methodology and wrote this report.

This work was conducted under the general supervision of COL James L. Kays, PhD, Professor and Head, DSE, USMA and BG Gerald E. Galloway, Jr., Dean of the Academic Board, USMA. Mr. Herbert Peuscheck is Deputy Director for General Purpose Programs, OSDPA&E. The Director of OSDPA&E is Mr. William Lynn.

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This bulk of this research was conducted during the period 28 June 1993 through 1 August 1993. The methodology and results contained herein are not to be construed as official Department of the Army (DA) or Department of Defense (DoD) position, policy, or decision. The methodology and results contained herein are solely the responsibility of the authors.

Executive Summary

The Office of the Director, Program Analysis & Evaluation (OSDPA&E), is planning to institute a Department of Defense (DoD)-wide Mission Area Analysis (MAA) program as a key element of the Planning-Programming-Budgeting System (PPBS) cycle. MAAs--broad analyses that treat the highest levels of force aggregation and provide cross-service, cross-mission perspectives--are an essential element of post-Cold War planning. MAAs, though prescribed in DoD Directive 5000.2, have yet to be defined formally within the DoD. The MAA program envisioned will examine, among other things, potential force structure and modernization tradeoffs that are essential to the formulation of an affordable long-term plan for defense resource allocation.

This work described herein was to develop methods for assessing capabilities of alternative force structures for warfighting and non-warfighting missions as part of the MAA process. This methodology proposed assesses joint force structure based upon warfighting requirements. Then, using a similar methodology, assess the capabilities of that force structure to perform non-warfighting missions. In the past, joint force structure analysis has often been policy driven and lacking in detailed objective analytical support. This report is an attempt to develop a methodology that will provide some analytical rigor to the process.

For now the warfighting force design process applies an integer programming (IP) model to make force-unit tradeoffs, using "Mission Capability Packages" (MCPs) as building blocks. The IP model, which may eventually evolve to a generalized mathematical program, determines efficient (i.e., non-redundant and effective) force mixes to accomplish given missions. In the model, MCPs are defined as integrated slices of the total force required to accomplish assigned missions. For example, a land combat MCP, which could have various configurations, would contain ground units, support units, lift assets for mobilization and deployment, and air assets for sustainment. By considering various MCPs, an assessment of efficiencies in total force capability and cost can be ascertained.

Requirements that determine the constraints for the IP are divided into seven classes: economic, personnel, operational, modern force, strategic, political, and support. These constraints are used to shape the force structure based upon policy, strategic, maximum warfighting capabilities, economic, etc., considerations. The exact makeup of these constraints can be obtained from a wide variety of sources to

include the functional MAA studies, defense planning guidance (DPG), congressional mandates, etc.

An example problem is presented to demonstrate the force design methodology. When possible, the best available input was used to ensure the methodology would produce reasonable results. However, because of the limited duration of the research, rough estimates were often used for input. This example problem is presented only to demonstrate the methodology. The results contained herein should not be construed as study quality.

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1. Introduction

1.1 Background

The U.S. maintains a military force for three reasons (Brown, 1989): to deter war, to win a war if war occurs, and to extend U.S. influence in peacetime. The size and mix of the force required to accomplish these goals is often driven by policy, strategic, and economic considerations. During the 1960s, former Secretary of Defense, Robert McNamara espoused the view that force structure for the DoD[1] should be the end product of a three-stage process by

- determining policy goals,
- determine the military capabilities to support the policy goals, and then
- calculate those forces which would provide the required capabilities at a minimum cost.

In reality, this process is very complicated and extends beyond providing sufficient military capabilities to maintaining an industrial complex, balancing that traditional roles and missions, and adjusting to a wide variety of political considerations.

During the cold war era, force structure was developed based mainly on strategic considerations. Often policy goals dictated the size and makeup of the DoD rather than efficiencies in acquiring maximum capabilities at minimum cost to meet threat requirements. Also, because of the relative high priority given to resourcing the DoD, overlapping service roles and missions and the conduct of non-warfighting missions was not a major concern in the force design process. However, as the defense budget decreases and the uncertain threat is redefined, overlapping roles and missions will be closely scrutinized as possible cost cutting

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[1] See Appendix A for a listing of all acronyms and abbreviations used in this report.

arenas. In addition, the force structure needed to support non-warfighting[2] missions will become increasingly important to the U.S. military. As the ability to extend U.S. influence becomes the dominant defense theme into the 21st century and the pressures of a resource constrained environment increases, non-warfighting capabilities must be addressed during the force structure design process.

An essential element of post-Cold War force design is broad analyses that treat the highest levels of force aggregation and provide cross-service, cross-mission perspectives. These analysis should address all possible types of operations that could lead to the commitment of DoD resources. Towards this end, the OSDPA&E is instituting a DoD-wide Mission Area Analysis (MAA) program as a key element of the Planning Programming Budgeting Cycle (PPBS) cycle. The MAA program envisioned will examine, among other things, potential force structure and modernization tradeoffs that are essential to the formulation of an affordable long-term plan for defense resource allocation.

The research described in this report was undertaken to develop methods for assessing capabilities of alternative force structures for war fighting and non-war fighting missions. For now, the approach applies an integer programming (IP) model to make force-unit tradeoffs, using Mission Capability Packages (MCPs) as building blocks. The IP model, is expected to evolve to a generalized mathematical program, determines efficient (i.e., non-redundant and effective) force mixes to accomplish given missions. In the model, MCPs are defined as integrated slices of the total force required to accomplish assigned missions. For example, a land combat MCP, which could have various configurations, would contain ground units, support units, lift assets for mobilization and deployment, and air assets for sustainment. By considering various MCPs, an assessment of efficiencies in total force capability and cost can be ascertained.

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[2] Non-warfighting is used in lieu of operations short of war or operations other than war (OOTW). OOTW has Army implications and a more broad term is needed.

Consistent with the philosophy of the DoD, the warfighting requirements drive the force structure[3]. However, the non-warfighting requirements must be accounted for or at least affect the force design process. Five main categories of non-warfighting missions are proposed: nation assistance; peacekeeping, humanitarian, and disaster (PHD); security; security of sea lanes, and show of force.

In the past, non-warfighting issues have often been policy driven (often regarded as "lesser included cases") and void of detailed analytical support. This report presents a methodology that will provide some analytical rigor to the total force structuring process. The results can then be used to perform tradeoff analysis to show how different force mixes affect the ability of the total force to perform warfighting and non-warfighting missions.

An IP was chosen as the optimization technique. The IP as the general solution technique offers the ability to "shape" the force structure subject to numerous types of constraints (also termed "requirements") derived from the MAAs and other sources. Also, an IP will produce an optimal solution with integer values for the various MCPs.

Ideally, theater level combat simulations should be used for the purpose of total force design. Unfortunately, designing total joint force structure through the use of simulations is not practical. The complexity and number of units in joint operations makes pure simulation a difficult to use and expensive decision tool. Also given the broad range of potential conflicts and the dynamic nature of the global security environment, simulation based analysis would require going beyond a specific scenario to avoid being suspect and open to criticism.

The best approach is an optimization technique, such as mathematical programming, which combined with simulation for data input and verification and validation (V&V), can evaluate capability trade-offs for force design. One important implication of the proposed methodology is the ability to perform

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[3] "The Army organizes, trains, and equips to fight and win the nation's war. That remains its primary mission. The leadership, organization, equipment, discipline, and skills gained in training for war are also of utility to the government in operations other than war." from Department of the Army Field Manual 100-5, "Operations", draft dated 19 January 1993.

tradeoff analysis for various MCPs. The MCPs could vary as a function of new equipment, force structure, readiness, etc. In this way insight can be gained into

- equipment tradeoff across services,
- roles of the guard and reserves, and
- usage of nontraditional force mixes.

1.2 Definitions

The following definitions relating to roles and missions were generalized or taken mainly from Department of the Army (DA), Field Manual (FM) 100-5 (see DA, 1993). Unless noted otherwise, the terminology herein is not a DoD standard and is applicable only in the context of this document.

Arms Control - Arms control encompasses any plan, arrangement of process regarding control over the numbers, types, and performance characteristics of weapons systems. Missions include providing personnel to monitor the proliferation of weapons and technology, verifying the status of arms control agreements, and in demilitarizing munitions and hardware.

Attacks and Raid - The DoD conducts attacks and raids to create situations that permit seizing and maintaining political and military initiative. Acts by conventional ground, air, or special forces acting independently or in concert are used to damage or destroy high-value targets or to demonstrate U.S. capability and resolve to achieve a favorable result.

Combating Terrorism - Combating terrorism has two major subcomponents--anti terrorism and counter terrorism. During peacetime, this is mainly accomplished by anti terrorism activities, which are passive measures taken to minimize vulnerability to terrorism.

Counterdrug Operations - Military efforts in this arena support and complement, rather than replace, the counterdrug efforts of other U.S. agencies, the states, and cooperating foreign governments. This can include, but not be limited to, collaboration with host nation army forces to prevent export of illegal drugs and nation assistance efforts to develop economic alternatives to production, exportation, and distribution of drugs.

Domestic Civil Authorities Support - When appropriate, governmental authority directs the armed forces to assist in domestic emergencies within the CONUS.

Military units support disaster relief, humanitarian assistance, and similar operations.

Force Structure - Describes the formal organization of weapons, people, and equipment used by DoD to perform it's various missions and roles.

Humanitarian Assistance and Disaster Relief - Humanitarian assistance operations provide emergency relief to victims of man-made disasters when initiated in response to domestic, foreign government, or international agency requests for immediate help and rehabilitation. Disaster relief operations include activities such as refugee assistance, food programs, medical treatment and care, restoration of law and order, damage and capabilities assessment and damage control (e.g., environmental cleanup, firefighting, etc.).

Insurgencies/Counterinsurgencies Support - U.S. military forces may assist either insurgent movements or host nation governments opposing an insurgency. The U.S. uses it military resources to provide support to a host nation's counterinsurgency operations in the context of foreign internal defense through logistical and training support.

Mathematical Programming - Mathematical modeling is concerned with the development of procedures for the purpose of maximizing the extent to which the goals of the decision maker are realized. Typically, this is accomplished by representing non mathematical reality by means of equations and other mathematical statements. Solution techniques usually involve matrix algebra techniques.

Mission Area Analysis - A resource constrained analysis that aids in allocating total defense resources to meet overall defense capabilities requirements.

Nation Assistance - Nation assistance supports a host nation's effort to promote development (ideally) through the use of host nation resources. Nation assistance typically involve vertical and horizontal construction missions. The goals of nation assistance are to promote long term stability, develop sound and responsive democratic institutions, develop supportive infrastructure, promote strong free-market economies, and provide an environment that allows for orderly political change and economic progress.

Noncombatant Evacuation Operations - Noncombatant evacuation operations relocate threatened civilian noncombatants from locations in a foreign country or host nation. These operations may involve U.S. citizens whose lives are in danger or could include selected host nation citizens or third country nationals.

Peace Enforcement - Peace enforcement operations are military operations in support of diplomatic efforts to restore peace between hostile factions which may not be consenting to intervention and may be engaged in combat activities. Peace enforcement implies the use of force or its threat to coerce hostile factions to cease and desist from violent actions.

Peacekeeping Operations - Peacekeeping operations support diplomatic efforts to maintain peace in areas of potential conflict. The U.S. may participate in peacekeeping operations when requested by the United Nations (UN), with a regional affiliation of nations, with other unaffiliated countries, or unilaterally. US personnel may function as impartial observers, as part of an international peacekeeping force, or in a supervisory and assistance role.

Roles and Missions - Operational roles and tasks performed by the DoD as designated by the President or Secretary of Defense.

Security Assistance - Through security assistance programs, the United States provides defense materiel, military training, and defense-related services by grant, loan, credit, or cash sales to further its national policies and objectives. The two primary components are the International Military Education and Training Program (IMETP) and the Foreign Military Sales Program (FMSP). The IMETP conducts international education and training in CONUS as well as host nation. The FMSP allows designated governments to purchase military equipment, services, and training from the United States.

Shows of Force - A show of force is a mission carried out to demonstrate U.S. resolve in which U.S. forces deploy to defuse a situation that may be detrimental to US interests or national objectives. They can take the form of combined training exercises, rehearsals, forward deployment of military forces, or the introduction and buildup of military forces in a region.

WEI/WUV (weapon effectiveness index, weighted unit value) - A subjective force or weapons scoring methodology.

1.3 Scope

This report contains six chapters. Chapter 1 contains background information. Chapter 2 presents an overview of the MAA concept. Chapter 3 presents a literature review of other efforts directed at developing a total DoD force structure. Also, any existing data or models for both warfighting and non warfighting missions will be presented to support the methodology. Chapter 4 contains the methodology developed for assessing joint force structure for

various roles and missions. Chapter 5 contains an example study used to demonstrate the methodology. The study presented in this chapter was performed only for proof of principal. Lastly, Chapter 6 contains the summary and conclusions section. The report contains two appendices. Appendix A contains a listing of all acronyms and abbreviations used in the report. The other appendix contains information relevant to the IP model and example problem.

2. Overview of Mission Area Analysis

2.1 Background

During the cold war era, strategic force structure was developed based mainly on policy considerations. Often these policy goals dictated the size and makeup of the DoD in lieu of maximum capabilities at the minimum cost to meet the threat requirements. Conducting non-warfighting missions was not of concern and did not enter into the force structure design process because of the shear size of the DoD. However, with defense budget cuts and a poorly defined threat, elimination of these overlapping roles and missions will be closely scrutinized as possible cost cutting measures. Detailed analysis will be performed to maximize capabilities as resources dwindle or are redirected away from pure warfighting elements (e.g., environmental cleanup, maintaining industrial complex, non-warfighting missions and training, aid to the defense industry in the former Soviet Union, etc.). An essential element of post-Cold War force design should be broad analyses that treat the highest levels of force aggregation and provide cross-service, cross-mission perspectives to optimize resource allocation.

Because of the reasons previously presented, a resourcing paradigm shift is occurring with the DoD (see Figure 2.1). In lieu of traditional organization resourcing (i.e., Army, Navy, Air Force, Marines, and others) budgeting, functional resourcing methods are being studied. The MAA program envisioned will examine, among other things, potential force structure and modernization tradeoffs that are essential to the formulation of an affordable long-term plan for defense resource allocation. These MAAs will cover a broad scope in terms of operations/missions, time frame and horizon encompassed, and force slices considered. The MAA will be used in the program review group (PRG) process as shown in Figure 2.2.

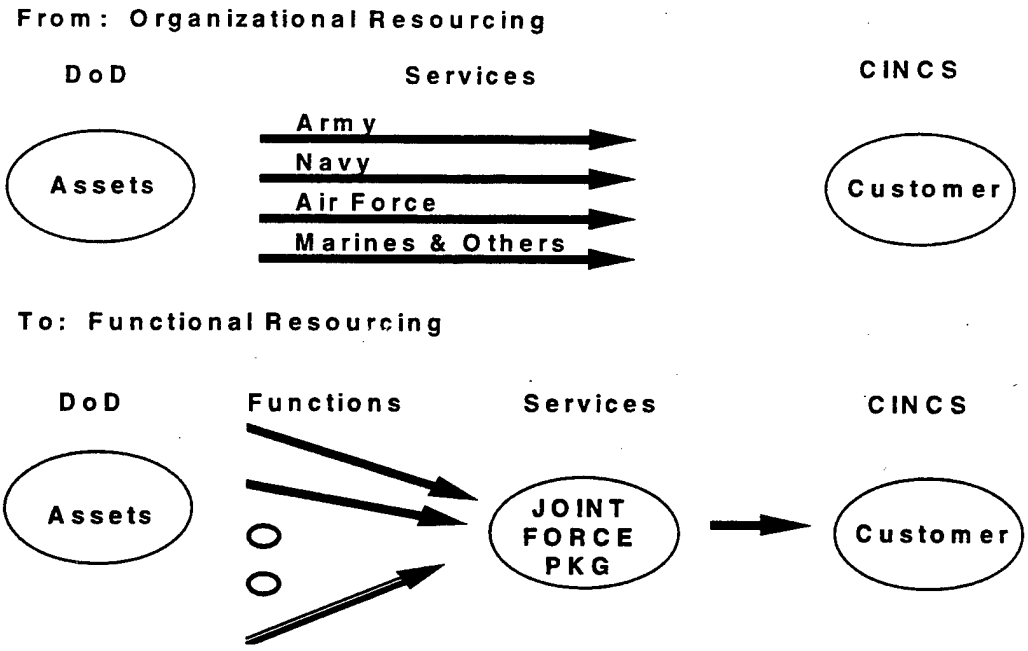

Figure 2.1 DoD resourcing paradigm shift

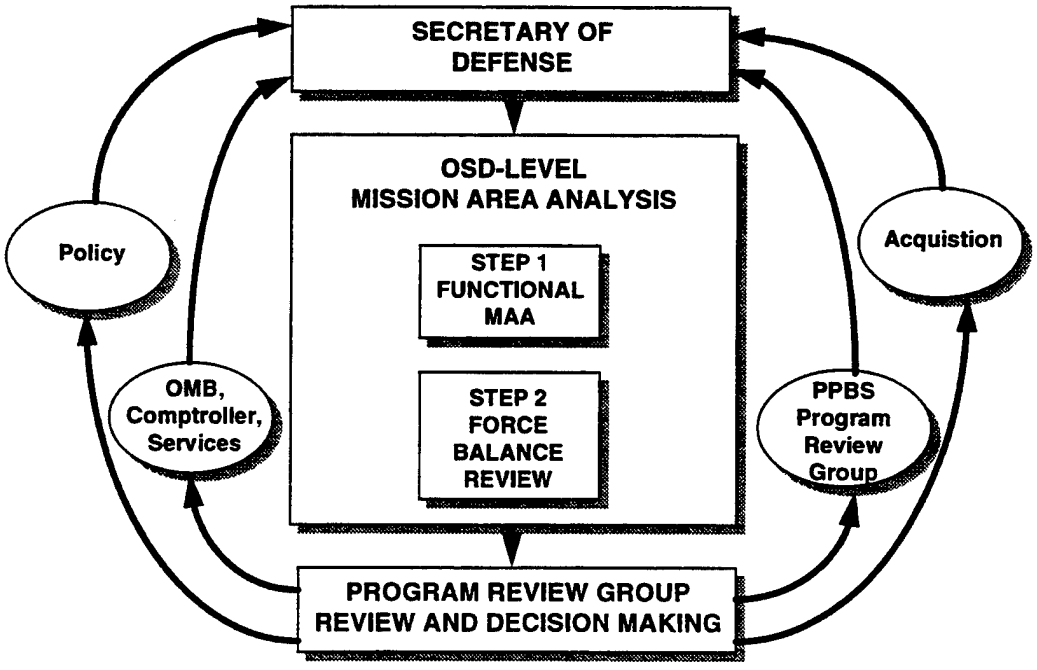

Figure 2.2 Impact of MAA on the PRG review and screening

2.2 Mission Area Analysis Concept

Mission Area Analysis has been defined as "a resource constrained analysis that aids in allocating total defense resources to meet overall defense capability requirements.[1]" Specifically, the MAA is an evaluation of needs for materiel acquisition and operational capability. The process takes a joint or cross-service perspective to certify collective needs and to explain redundancy or complimentary service requirements. The MAAs are designed to cover a broad scope in terms of operations and missions examined. MAA will be conducted in twelve function areas and are

- Combat Power On Land
- Command of the Sea
- Air Control/Superiority
- Power Projection - Conventional
- Operations Other Than War
- Lift (strategic and Tactical)
- Logistics
- Training
- Information Warfare
- Power Projection - Nuclear
- Technology Development
- Space Exploitation

Figure 2.3 shows how the MAAs will be developed and some of the primary outputs. The results from the MAAs will be used to conduct a total force capability analysis. This total force capability analysis will consist of a force balance integration process. This process is shown in Figure 2.4.

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[1] DOD Directive 5000.2.

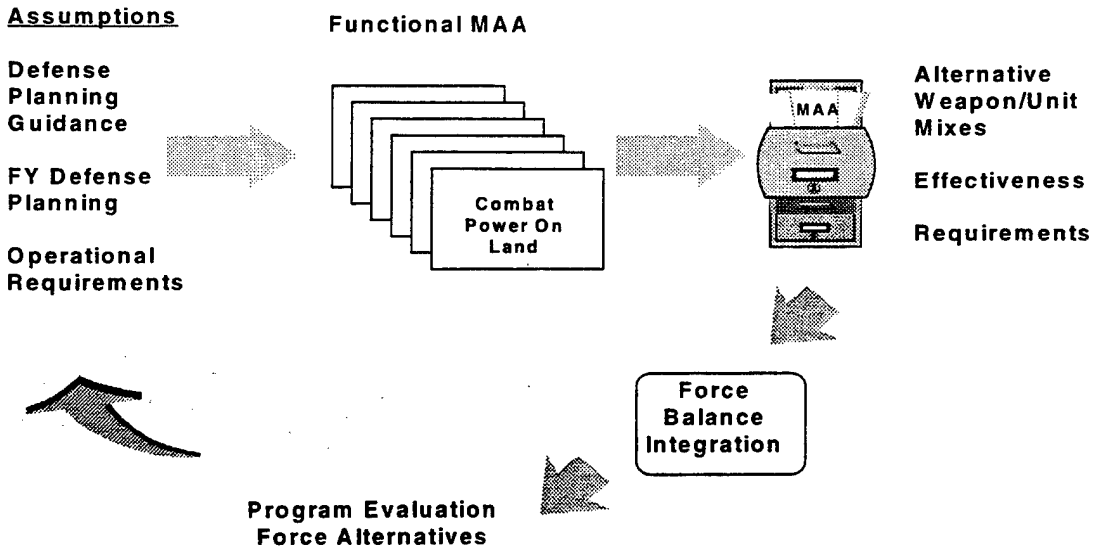

Figure 2.3 Development and outputs of an MAA

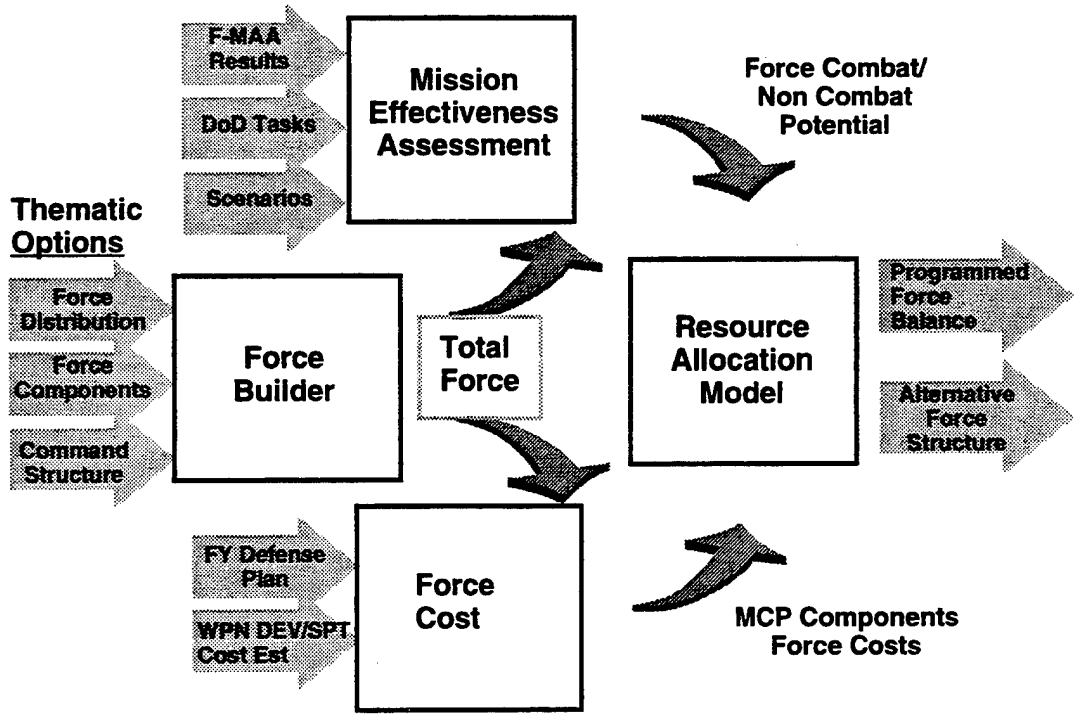

Figure 2.4 Force balance integration process

As shown in Figure 2.4, the results of the force balance integration process will produce alternative force structures. These alternative force structures will provide **insight** into the resource allocation process.

3. Literature Review

3.1 Introduction

A literature review was conducted to

- quantify non-warfighting missions,
- review the literature to determine what methodology has been used to determine joint force structure for warfighting,
- obtain validation data to support the methodology presented herein, and
- catalog input data and methodology that could be used for any studies.

Results from this literature review revealed that a significant amount of research had been performed to determine warfighting force structure. Also, a lot has been written about non-warfighting roles and missions. As expected, no research was identified to assess the force mix tradeoffs based upon warfighting and non-warfighting capabilities.

The 1991 Defense Authorization Act required the military service to drastically reduce active, guard, reserve, and civilian manpower. By the year 1995, most active components will have been reduced by 35% of the Desert Storm peak. As shown in Figure 3.1, the DoD has historically not drawn down the force and preserved readiness. Yet today, the roles and missions performed by the DoD are more complex and diverse that any time in history. How to shape the total force to be ready and trained in the event of another major regional conflict and yet perform a wide variety of non-warfighting missions, will be the theme of many studies.

The following sections contain the results of the literature review. The information discussed below is by no means inclusive.

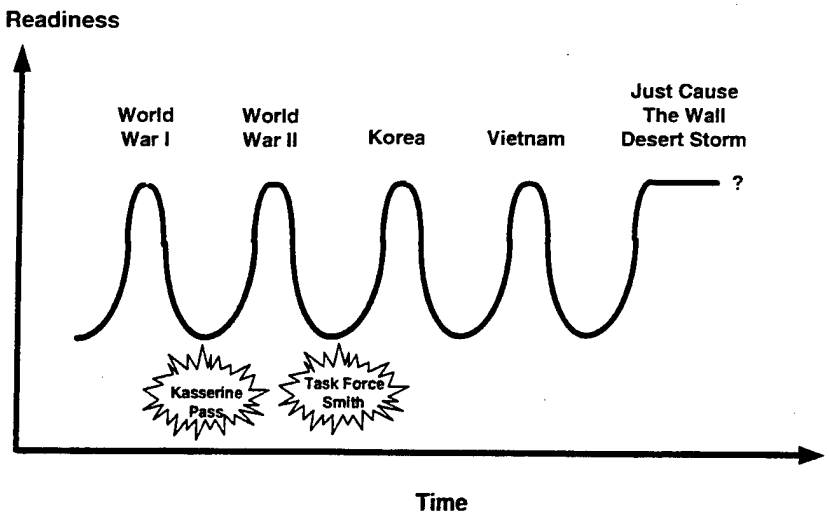

Figure 3.1 Historical readiness versus time plot for the DoD

3.2 Roles and Missions

With the end of the cold war and the increasingly dynamic nature of today's security environment, the threats to the U.S. and her allies during the remainder of this century will be from regional ethnic and cultural conflicts, drug trafficking, the proliferation of conventional military weaponry, high technology weaponry in the hands of potential adversaries, and weapons of mass destruction (Motley, 1993). Regional instabilities will require that U.S. forces remain at a high state of readiness. Also, the requirement to project forces from a CONUS deployed defense will require more joint and combined operations. Examples of threats to the U.S. national interest (from Motley, 1993) are

- the eventual disposition of nuclear weapons and technicians of the former Soviet Union (the fragmentation of the USSR has left nuclear-armed missiles located on the territories of Russia, Byelarus, Ukraine, and Kazakhstan);
- the inventory of conventional military equipment in Russia and the other republics which comprise the Commonwealth of Independent States;
- regional instability and wanton criminal behavior by local despots and fanatics as currently reflected in the former Yugoslavia and Somalia;
- weapons and technology proliferation which greatly enhance, in a short period of time, a country's threat capabilities;

- ethnic, religious and cultural strife, as recently demonstrated in India;
- drug trafficking;
- renegade states such as Iran, Iraq, Libya, and North Korea;
- terrorism;
- poverty and population growth in Third World countries; and
- environmental degradation.

With the emergence of the UN in the post cold war era, non-warfighting methods will be one of the dominant methods for promoting regional stability. Also, non-warfighting means will be the primary tool by which U.S. influence will be extended. In order to evaluate the capabilities of the U.S. armed forces in accomplishing these missions, they must first be defined, then categorized, and appropriate measures of effectiveness (MOE) developed.

The DA has categorized the non-warfighting missions of the Army (note that the definitions for these missions are contained in Chapter 1) into thirteen distinct classes (see DA, 1993). These classes are

- Nation Assistance,
- Security Assistance,
- Humanitarian Assistance and Disaster Relief,
- Support to Counterdrug Operations,
- Peacekeeping Operations,
- Arms Control,
- Combating Terrorism,
- Show of Force,
- Attacks and Raids,
- Noncombatant Evacuation Operations,
- Peace Enforcement,
- Support for Insurgencies and Counterinsurgencies, and
- Support to Domestic Civil Authority.

Security of Sea Lanes should probably be added to the list to make it all encompassing for the DoD.

A historical analysis of the numbers, personnel and equipment requirements, and contributions of these types of missions has been conducted by the CAA (see Headen and Kearn, 1991). The CAA study examined non-warfighting missions of Army personnel during the period 1975 through 1990. Though the study used different categories than those previously presented, they

do provide some insight into the trends of number of non-warfighting missions. These results are shown in Table 3.1.

Table 2.1 Summary of Army missions from 1975 through 1990 (from Headen and Kearn, 1991)

a. 1975 through 1979

Mission	75	76	77	78	79
Combat Operations	-	-	-	-	-
Peacekeeping	-	-	-	-	-
Show of Force	-	-	-	-	-
Security Augmentation	-	-	-	-	-
Nation Building	-	-	-	-	-
Humanitarian Assistance	1	-	1	2	1
Disaster Assistance	-	-	1	5	-
Support to Law/Other Agencies	-	-	-	-	-
Refugee Resettlement Operations	1	-	2	-	-

b. 1980 through 1989

Mission	80	81	82	83	84	85	86	87	88	89
Combat Operations	-	-	2	-	-	-	-	-	-	1
Peacekeeping	-	-	1	1	1	1	1	1	1	1
Show of Force	-	-	-	-	-	-	-	-	1	-
Security Augmentation	-	-	-	-	-	-	1	2	5	5
Nation Building	-	-	-	-	1	2	4	4	5	4
Humanitarian Assistance	1	-	-	-	-	1	1	-	-	-
Disaster Assistance	2	-	1	-	-	1	-	1	1	5
Support to Law/Other Agencies	-	1	1	1	-	-	-	1	-	1
Refugee Resettlement Operations	3	1	-	-	-	-	-	-	-	-

c. 1990

Mission	90
Combat Operations	1
Peacekeeping	1
Show of Force	-
Security Augmentation	-
Nation Building	2
Humanitarian Assistance	-
Disaster Assistance	1
Support to Law/Other Agencies	-
Refugee Resettlement Operations	-

With dwindling defense resources, the roles and missions controversy has received much attention. Whether in terms of the individual services or the total DoD, a lot has be written about roles and missions (see Chairmen of the Joint Chiefs of Staff, 1993, or Blechman et al., 1993) to both justify the defense budget and reapportion the individual service roles to reduce redundant capabilities as a budget reducing consideration. Any force design analysis must be sensitive to historical roles and missions.

3.3 Joint Warfighting Force Structure Evaluation Methodology

A significant amount of research has been performed to address force structure at the individual service levels. For example, the CAA's mission is to perform research to support that requirement for the Army. At the various Department of the Army, Navy, and Air Force levels, force structure for the individual services is an ongoing process. However, at the DoD level less research is performed to design the total force. The force composition mandated by DoD is primarily performed by the Joint Chiefs of Staff.

In order to perform force structure evaluation, some methodology must be used to assess both friendly and threat capabilities. The Rand Corporation (Bennett, 1990) defines three types of capabilities assessment methodologies:

- **static aggregates** which are applied in comparing forces which could be used in any of several theaters. These aggregates should compare forces without considerations to the environment in which they will be used, but do include weapon and unit performance factors.

- **situational aggregates** are applied when comparing forces in a specific theater context before the details of operational/tactical employment are known. These aggregates should compare forces in a regional combat environment, including assessments of weapons systems, unit performance, and average terrain and environmental issues.

- **dynamic combat adjudication** is applied when assessing the outcomes of a particular combat situation. Such assessments should include consideration of weapon systems performance (including such effects as artillery fire suppression), the impact of high technology weapon systems, type of battle, the character of maneuver, unit performance, terrain, other environmental issues, and scale of battle.

Any of these methodologies can provide insight into the problem. However, no single technique is all encompassing and will produce the "best" answer.

Static and situational aggregates force scoring techniques are based upon WEI/WUVs and are the subject of much criticism. Many analysts regard WEI/WUVs as difficult to objectively determine. Therefore, many analysts view any study conducted with any kind of static or situational aggregation technique as unacceptable. However, Bennett (1990) argues that even though WEI/WUV based force scoring do not account for the synergistic effects of many weapons, there is a role for both static and situational aggregated force scoring. Bennett (1990) argues that many of the requirements for comparing military forces are very general and that even when a force deployment is made, the precise tactical employment of the force is not known. Thus, some relative comparison of forces is required. Given the dynamic nature of today's security environment, static and situational aggregated force scoring have a place in the defense analytical community.

Situational aggregation techniques have been the basis for many military related decisions. DuPuy's work (DuPuy, 1987) is probably the most widely recognized and has been used for many military studies to include assessing threat capabilities and treaty negotiation. The Rand Situational Force Scoring (SFS) methodology (Allen, 1992) is also a situational aggregation technique and is very similar to DuPuy's work. The SFS methodology deals mainly with ground combat is mainly used as a source of data to improve land warfare in aggregated combat models.

Another weapons scoring methodology that has been used extensively is the Technique for Assessing Comparative Force Modernization or TASCFORM[1]. TASCFORM has eight hardware assessment submodels. TASCFORM is neither a true static nor situational aggregation technique in that it uses subjective and objective weapons characteristics and performance data. The weapons systems performance data produce from TASCFORM has been used extensively for high level DoD force structure analysis and was used to help develop the current FY95 base force structure.

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[1] TASCFORM is a trademark of The Analytical Sciences Corporation, Arlington, Virginia.

All three of the above discussed force scoring techniques have been used in force structure evaluation. Very little, if any, joint total force design work has been performed using simulation. Numerous situtational joint simulation studies have been performed for operational planning.

3.4 Non-warfighting Force Structure Evaluation Methodology

Until the recent defense cuts, roles and missions controversy, and the expanded role of the U.S. in UN peacekeeping operations, the incorporation of non-warfighting missions into the total force structure analysis process was probably nonexistent. Some research has been performed to define the optimal force mix for peacekeeping, humanitarian, and disaster (PHD) missions. For example, Blechman et al. (1993) recommends the creation of two light infantry divisions and six surveillance/monitoring battalions specifically trained and equipped to perform UN peacekeeping activities. The justification for that level of commitment was hopefully based upon some objective analysis.

Beyond these types of subjective studies for PHD, little has been written about non-warfighting capabilities. As the number of units in the base force continues to be reduced, the ability of the U.S. military to respond and accomplish non-warfighting missions will diminish. Limited redundant service capabilities, significantly reduced research and development (R&D) funding towards non-combat support equipment, and the increased role of the guard and reserves in areas that would traditionally perform non-warfighting missions (i.e., engineers, military police, etc.), will also contribute to a reduced capability. Force structure analysis for non-warfighting missions is important in the event the U.S. becomes involved in any major regional conflicts (MRCs). In the past, additional troops were available for these types of missions because of the sheer size of the DoD. The U.S. cannot afford to abandon all non-warfighting missions throughout the world during a MRC.

In order to quantify the capabilities for non-warfighting roles and missions, the general categories shown in Table 3.2 were identified. The fourteen non-warfighting roles and missions in the left column of that table were take mainly from DA, Field Manual 100-5 (see DA, 1993). This groupings on the right are proposed general categories for OOTW or non-warfighting missions. After the force structure has been determined based upon warfighting requirements,

the capabilities of that force structure to perform those missions will be addressed.

Table 3.2 Non-warfighting mission categories

Detailed Categories	General Categories
Nation Assistance	Nation Assistance
Humanitarian and Disaster Relief Peacekeeping Operations Peace Enforcement	Peacekeeping, Humanitarian, Disaster (PHD)
Security Assistance Support to Counterdrug Arms Control Combating Terrorism Attacks and Raids Noncombatant Evacuations Arms Control Insurgencies/Counterinsurgencies Support to Domestic Civil Authorities	Security
Show of Force	Show of Force
Security of Sea Lanes	Security of Sea Lanes

For the example problem presented in Chapter 5, the only non-warfighting mission capability evaluated was nation assistance. The major MOE used for assessing a unit's ability to perform nation assistance mission was horizontal construction capabilities. Some proposed MOEs for the five major non-warfighting mission categories shown in Table 3.2 are presented in Table 3.3.

Additional research is needed to accurately define the MOEs for non-warfighting missions. Fortunately, many of the individual services perform this research in an effort to better justify their individual force structure. For example, the U.S. Army Engineer Strategic Studies Center has performed extensive research to quantify work rates for various pieces of engineer equipment. Historical analysis can be performed of these other non-warfighting mission to identify the major missions conducted and subjective or objective techniques can be used to assess the capability of given units to perform those missions.

Table 3.3 MOEs for the five major non-warfighting mission categories

Non-warfighting Mission	Major MOEs
Nation Assistance	horizontal and vertical construction capabilities, in-theater costs
PHD	mobilization time, sustainability, in-theater costs
Security	mobilization time, sustainability, in-theater costs, lethality
Show of Force	mobilization time, combat potential, in-theater costs
Security of Sea Lanes	sea combat power, sea mobilization time, in-theater costs

4. Resource Allocation Methodology

4.1 Introduction

Consistent with the philosophy of the DoD, the warfighting requirements must drive the force structure. Then, the non-warfighting capabilities should be evaluated based upon that force structure so that meaningful tradeoff analysis can be conducted. As previously discussed, non-warfighting means will be the primary method by which U.S. influence will be extended in the future. The proposed methodology uses a similar formulation, input data, and level of aggregation to compare the warfighting and non-warfighting capabilities.

Ideally, theater level combat simulations should be used for the purpose of total force design. Unfortunately, the issue of joint force structure is not necessarily a pure resource allocation/optimization problem because of strategic and policy concerns. This, combined with the complexity and number of units in joint operations makes pure simulation an expensive decision tool. Given the history of the analytical community in predicting potential conflicts and the dynamic nature of the global security environment, any analysis such as simulation based upon a specific scenario would also be suspect and open to criticism. Ideally, some type of optimization technique, combined with simulation for data input and verification and validation (V&V), and that is capabilities driven should be used for force design at a gross level.

A mathematical program (MP)[1] was chosen as the optimization technique. Specifically, a integer program (IP) type of MP is proposed. The MP as the general solution technique offers the ability to "shape" the force structure subject to numerous types of constraints that must be addressed. Also, an IP will produce an optimal solution with integer values for the various MCPs.

The proposed methodology presents several new concepts for joint force structure evaluation. In an effort to ascertain the total costs of performing a mission, the idea of mission capabilities packages (MCPs) is proposed. These MCPs include the forces required for mobilization, combat, combat support, and demobilization to fulfill or conduct a mission area requirement. This will allow for assessing the total costs across the services to field a warfighting and support capability. Using an IP as the optimization technique, a force structure (based solely on combat) is developed based upon a wide variety of constraints. Then

[1] The reader is referred to any undergraduate text on operations research or systems engineering for a discussion of mathematical programming.

using this force structure, non-warfighting capabilities are evaluated. Sensitivity analysis can then be performed to ascertain how changes in force structure affect warfighting and non-warfighting missions, identify excess resources, and identify those MCPs that are the most cost effective.

After the MAAs have defined the requirements for the total force in terms of certain types or categories of units, certain MCPs are contrived to develop the optimum force mix to meet the requirements. For example, one of the major results from the Combat Power on Land MAA might be the requirement for roughly four heavy division equivalent's worth of assets to support two simultaneous major regional conflicts (MRCs). Examples of MCPs that could fulfill this requirement are shown in Table 4.1.

Table 4.1 MCPs that could meet the land combat heavy requirements

Component	Heavy Division Package Active	Heavy Division Package Reserve	Separate Heavy Brigade Package Active	Separate Heavy Brigade Package Reserve
Heavy Division	X	X		
Separate Heavy Brigade			X	X
Division CS Support	X	X		
Division CSS Support	X	X		
Close Air Support Assets	X	X	X	X
Lift Assets for Division	X	X		
Lift Assets for Brigade			X	X

The proposed methodology is based loosely on the Army's Value Added Analysis (VAA, see Koury, 1992). One of the important implications of the proposed methodology is the ability to perform tradeoff analysis for various MCPs across service. The MCPs could vary as a function of new equipment, force structure, readiness, etc. Questions such as

- equipment tradeoff across services,
- roles of the guard and reserves, and
- usage of nontraditional force mixes

could be addressed at a very gross level.

4.2 Warfighting Force Structure Methodology

The approach taken for determining the force for warfighting was to develop a IP that maximizes a combat power value subject to a family of constraints based upon numerous political and operational considerations. The IP would produce the number and types of MCPs based upon the constraints imposed.

4.2.1 Mission Capabilities Packages

The idea of MCPs has previously been presented and is used in an effort to ascertain total costs. The following MCPs were contrived for example problem:

Table 4.2 Mission capabilities packages

a. Land Combat Package Light (LCPL)

Component	Airborne Division Package - Active
Airborne Division	X
Division CS	X
Division CSS	X
Air Lift Assets	X

b. Land Combat Package Medium (LCPM)

Component	Light Infantry Division Package Active	Armored Cavalry Regiment Package Active	Marine Expeditionary Force Package Active	Air Assault Division Package Active	Separate Infantry Brigade Package Active
Light Infantry Division	X				
Armored Cavalry Regiment		X			
Marine Expeditionary Force			X		
Air Assault Division				X	
Separate Infantry Brigade					X
Division CS Support	X			X	
Division CSS Support	X			X	
Marine Close Air Support Assets			X		
Close Air Support Assets	X				X
Lift Assets for Division	X			X	
Lift Assets for Brigade		X			X
Resupply Ships	X	X	X		X
Amphibious Warfare Ships			X		
Propositioned Marine Assets			X		

b. continued

Component	Light Infantry Division Reserve Package	Armored Cavalry Regiment Reserve Package	Marine Expeditionary Force Reserve Package	Separate Infantry Brigade Reserve Package
Light Infantry Division	X			
Armored Cavalry Regiment		X		
Marine Expeditionary Force			X	
Separate Infantry Brigade				X
Division CS Support	X			
Division CSS Support	X			
Marine Air Wing			X	
Close Air Support Assets	X	X		X
Lift Assets for Division	X			
Lift Assets for Brigade		X		X
Resupply Ships	X	X	X	X
Amphibious Warfare Ships			X	
Propositioned Marine Assets			X	

c. Land Combat Package Heavy (LCPH)

Component	Heavy Division Package Active	Heavy Division Package Reserve	Separate Heavy Brigade Package Active	Separate Heavy Brigade Package Reserve
Heavy Division	X	X		
Separate Heavy Brigade			X	X
Division CS Support	X	X		
Division CSS Support	X	X		
Close Air Support Assets	X	X	X	X
Lift Assets for Division	X	X		
Lift Assets for Brigade			X	X

d. Power Projection Package (PPP)

Component	Carrier Battle Group Package Active	Forward Deployable Aircraft Package Active	Forward Deployable Aircraft Package Reserve	Surface Action Group Package Reserve	Surface Action Group Package Active
Carrier at Sea	X				
Carrier in Port	X				
Combat Support Ships	X			X	X
Direct Support Ships	X			X	X
Support Aircraft (Navy)	X			X	
Fighter Aircraft (Air Force)		X	X		
Support Aircraft (Air Force)		X	X		

e. Training Package (TP)

Component	Carrier Battle Group Package Active	Cadre Division Package Active
Carrier at Sea	X	
Combat Support Ships	X	
Direct Support Ships	X	
Cadre Division		X
Division CS		X
Division CSS		X

f. Special Operations Force Package (SOF)

Component	SOF Navy Package Active	SOF Army Package Active	SOF Navy Package Reserve	SOF Army Package Reserve	Ranger Battalions Package Active
SOF Navy Group	X		X		
SOF Army Group		X		X	
Ranger Battalions					X
Navy Lift Assets	X		X		
Air Lift Assets	X	X	X	X	X

g. Undersea Warfare Package (UWP)

Component	Attacks Submarine Package
Attack Submarine at Sea	X
Attack Submarine in Port	X

h. Long Range Air-to-Ground Package (LRAGP)

Component	Heavy Bombers Package Active
Air Resupply Asset	X
Heavy Bombers Wing	X

i. Reconnaissance, Intelligence, and Electronic Warfare Package (RIEP)

Component	Reconnaissance and Intelligence Package Active	Reconnaissance and Intelligence Package Reserve
Reconnaissance Wing	X	X
Intelligence Wing	X	X

j. Mine Warfare Package (MWP)

Component	Mine Warfare Package Active	Mine Warfare Package Reserve
Mine Warfare Ship at Sea	X	X
Mine Warfare Ship in Port	X	X

k. Anti Undersea Warfare Package (AUWP)

Component	Anti Submarine Fixed Wing Package	Anti Submarine Rotary Wing Package	Anti Submarine Fixed Wing Package	Anti Submarine Rotary Wing Package
Fixed Wing ASW Squadrons	X		X	
Rotary Wing ASW Squadrons		X		X

l. National Assistance Package (NAP)

Component	U.S. Army Corps of Engineers	U.S. Coast Guard
Civil Works Missions and Facilities	X	
Coast Guard Units		X

m. Nuclear Deterrence Package (NDP)

Component	ICBM Missile Package
ICBM Missile Wings	X

n. Intelligence Agencies Package (IAP)

Component	Intelligence Agencies Package
Intelligence Agencies	X

o. Space Operations Package (SOP)

Component	Space Operations Package
DoD Space Commands	X

p. Administrative Package (AP)

Component	Administrative Package
DoD and Service Staffs	X

Hopefully, the MAA process (see Figure 2.3) would produce similar results. The previous listing is by no means all-encompassing. However, the various roles and missions of the DoD should be reflected.

During wartime operations, these MCPs can interact for joint operations. Also, they can be any force or equipment structure mix. For example, round out brigades, units with new equipment, or conceptual force mixes not traditionally used. The concept of using MCPs is to compartmentalize individual units that provide a capability in order to ascertain true costs. These, the MCPs will be the decision variables for the IP. However, the requirements definition (i.e.,

constraints) will be developed based upon the MAAs, CINC requirements, policy considerations, etc.

The MCPs can be created at any echelon. In an effort to maintain a consistent level of aggregation, the typical MCPs are built around Army Brigades or Divisions, Navy Carrier Battle Groups, and Air Force Wings. In some instances, smaller unit sizes are needed to capture the total responsibilities of the DoD. In addition, support operations (administrative, nation assistance, intelligence, space operations, etc.,) are included so that economic tradeoffs between true combat units and support operations can be performed.

4.2.2 Objective Function Coefficients

Once the "make-up" of the MCPs has been determined, the next step is to start formulation of the IP. Like any MP, an IP has two components; an objective function and constraints. An objective function must represent the conditions which must be optimized (profit, cost, time, energy, etc.,).

4.2.2.1 Combat Potential Based Objective Function

For force structure design, you could maximize some measure of combat power in the desert, mountains, or some combination of the two. Or, depending upon your perspective, you could minimize personnel or costs. Any force structure analysis should be requirements driven. Ideally, maximization of a generic measure of combat power should be used for the objective function coefficients. These generic measures of combat power will be referred to as **combat potential**.

Figure 4.1 presents one type of methodology that could be used for determining combat potential (objective function coefficients). One method would be to subjectively weight values of sustainability, force capability, and mobilization for some type of linear additive model. This concept can be expressed mathematically as

$$CP_i = \alpha_{cp} FC_i + \beta_{cp} S_i + \delta_{cp} M_i \qquad (4.1)$$

where

CP_i = objective function coefficient, i.e., combat potential value for mission capability package i (see Table 4.1)
FC_i = force capability or combat power for mission capability package i
S_i = sustainability value for mission capability package i
M_i = mobilization value for mission capability package i
$\alpha_{cp}, \beta_{cp}, \delta_{cp}$ = subjective weights

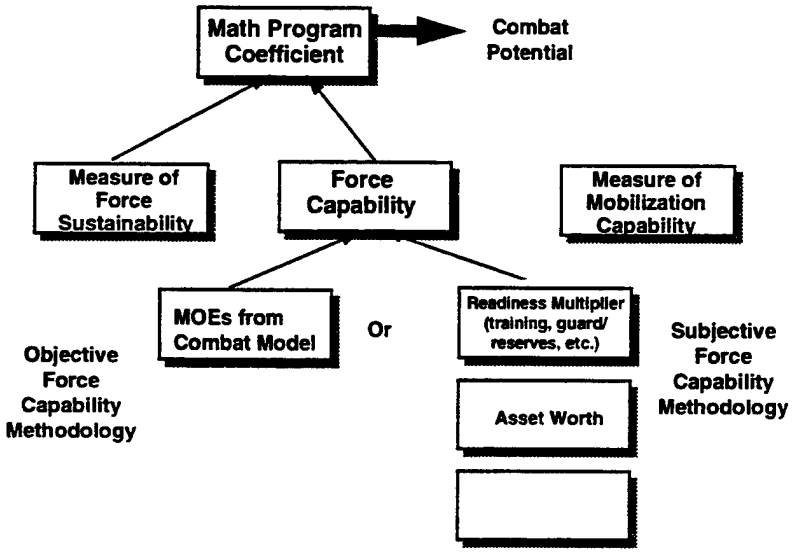

Figure 4.1 Methodology to determine warfighting potential calculations

The force capability value could be determined using either static or situational aggregates of from some type of combat model. If some type of aggregation technique is used, you would simply sum the weapons multiplied by the asset worth (WEI/WUV). Multipliers could then be used to modify the capability of the asset worth to develop situational aggregation values.

Ideally, a theater level combat simulation would be used to quantify the force capability of the various MCPs and not rely on subjective values for asset worth. If a combat simulation model is used to determine force capability, some type of linear additive model could also be developed to develop force capability from critical MOEs. Force capability based upon combat model derived MOEs might be expressed as

$$FC_i = \sum_{i=1}^{n} (\alpha_{FC} BL_i + \beta_{FC} FER_i + \delta_{FC} TBC_i) \quad (4.2)$$

BL_i = blue losses for mission capability package i
FER_i = force exchange ratio for mission capability package i
TBC_i = time to battle completion for mission capability package i
α_{FC}, β_{FC}, δ_{FC} = subjective weights associated with the importance of the MOE

The drawback to this approach is that simulation results are scenario dependent. Various scenarios (terrain, weather, etc.) must be incorporated into the process. However, the complexity dramatically increases.

4.2.2.2 Deployability Based Objective Function

Another possible method is to develop an objective function that accounts for changes in combat potential as a function of time. For example, Equation 4.1 could be rewritten as

$$CP_i = f(t)\, \alpha_{CP} FC_i + \beta_{CP} S_i \quad (4.3)$$

The f(t) function would account for deployability. For example, an airborne unit can respond by placing a brigade on the ground in 36 hours. However, it takes several months to fully mobilize a heavy division. By including this function, force structure mixes can be determined for various mobilization times.

Many proponents of modern warfare believe that deployability should be one of the keys to force design. Recent experience has validated this viewpoint.

4.2.2.3 Sustainability

Sustainability is one of the key components of non-warfighting force design since it is directly proportional to costs. Several methods exist to asses sustainability values for Equations 4.1 and 4.3. Values for sustainability might be

determined subjectively or objectively. For example, a good objective measure of sustainability might be the petroleum, oil, and lubricants (POL) and ammunition expenditure rate during combat operations. This equation would take the form of

$$S_i = \sum_{i=1}^{n} (POL_i + AE_i) \qquad (4.5)$$

where

POL_i = POL requirements for mission capability package i
AE_i = ammunition expenditure for mission capability package i

Note that the sustainability, mobilization, and force capability values should all be normalized between 0 to 1. All values should be normalized by taking the maximum value for the variable and setting it equal to 1. Then, the minimum value for that variable should be set equal to 0. Then, all other values should be linearly scaled between the 0 and 1 end-points.

4.2.2.4 MAA Results Derived Objective Function

The most logical methodology for determining objective function coefficients would be to develop a matrix of candidate MCPs. Then, let those MCPs be evaluated and modified as part of the MAA process. Then some type of mapping could be developed based upon subjective or qualitative weighting of "importance" using a relative numerical scale. Techniques exist for performing these types of mappings. However, much research is needed to determine if the results are meaningful.

4.2.3 Mathematical Program Constraints

For the proposed methodology, categories of constraints similiar to those shown below are proposed:

- Economic Considerations
- Personnel Considerations
- Operational Considerations - Active Forces
- Operational Considerations - Reserve Forces
- Modernization Considerations
- Strategic Considerations
- Support Operations
- Political Considerations

The constraints should be formulated in such a manner that the requirements are reflected in terms of MCPs. These constraints would be developed from a wide variety of sources to include MAAs, DPG, CINC requirements, administration policy, congressional mandates, etc.

4.2.3.1 Economic Considerations

Ideally, any type of tradeoff analysis should delineate between the costs associated with sustaining during peace and mobilizing for war, support during war, and demobilizing after the operation. The peacetime costs should be used in developing the costs associated with the MCPs. Typical cost categories are shown in Table 4.3. This costing methodology should account for all "hidden" costs associated with that unit performing its combat mission.

Table 4.3 Sample cost categories for MCPs

Specific Cost Categories	General Cost Categories
training new equipment repair and maintenance of equipment and facilities base operations life cycle and actual personnel environmental damage and/or cleanup	direct costs - sustainment
air and sea lift maintenance, training, personnel for lift relevant acquisition programs	indirect costs - mobilization, and demobilization
combat support and combat service resupply	indirect costs - combat support
research and development (R&D)	indirect costs - R&D

In many respects determining costs are more difficult than determining the combat potential values. The costs presented in Table 4.3 might not be usable in the form presented. Another methodology for generalizing costs might be to make the categories compatible with those presented in the Program Objective Memorandum (POM).

Cost constraints can also serve another function -- to ensure individual identities of the services. By establishing costs "ceilings" and "floors" on the budget authority for each service, individual identities can be maintained.

4.2.3.2 Personnel Considerations Requirements

The argument can be made that personnel constraints should be the product of the analysis instead of a constraint contributing to "shaping" the force structure. If manpower constraints are used to help determine the force structure, they can be added for the individual services or the total force structure as stated as a constraint. Personnel constraints could also be used to ensure the identity of the individual services.

4.2.3.3 Operational Requirements

Operational constraints are the most critical to shaping the force structure because they are used to reflect the warfighting requirements. For example, a commitment to winning two major regional conflicts (MRCs) requires a minimum number of certain types of MCPs. Other examples of operational requirements that can be reflected as constraints are some MCPs are mandated by law while others are essential to combat operations in a support role. Whether the operational requirements should be separated for active and reserve units needs more research. From a pure optimization perspective they should not be separate. However, the political realities associated with the active-guard-reserve mix will probably require a minimum number and types of guard and reserve units. This will necessitate constraints dealing solely with the number of guard and reserve units.

4.2.3.4 Modernization Requirements

Any type of total force structure analysis should address equipment modernization. These types of issues are critical in terms of political and industrial base considerations. For example, the DoD has invested billions of dollars in the construction of new aircraft carriers and nuclear attack submarines. Even though the strategic role of these ships has diminished since the end of the cold war, it is highly unlikely that these ships will be decommissioned because of the capital investment. Certain key defense technologies must be maintained. These technologies can best be preserved through modernization programs.

4.2.3.5 Strategic Requirements

Because combat potential values are derived from scenarios using conventional weapons, the force structure derived from the IP will not reflect any strategic requirements. Because this is a requirement for our defense forces, certain units must be maintained -- even though they can contribute little directly to a conventional war. The MAAs, treaty requirements, etc., will dictate what strategic resources (international continental ballistic missile or ICBMs wings, rail garrison, Midgetman, etc.,) must be maintained.

4.2.3.6 Support Requirements

Certain key activities must be maintained by the DoD. For example, intelligence, space operations, national assistance (Coast Guard and Corps of Engineers), and administrative activities contribute to the day-to-day operations and strategic missions of the DoD. Because they are funded under the DoD budget, they should be included as MCPs. By including these elements, tradeoff analysis of these elements can be conducted along with the MCPs.

4.2.3.7 Political Requirements

Some of the requirements used in shaping force structure can be construed as political in nature. For example, the active-guard-reserve issues and the requirement to maintain an industrial base in certain key defense arenas could be viewed as a political considerations and must be included in any type of meaningful analysis.

4.3 Non-warfighting Capabilities Evaluation Methodology

Once the force structure has been determined, an assessment of the non-warfighting potential must be evaluated. Figure 4.2 presents a methodology to determine this non-warfighting potential value. Like the combat potential, simulations or subjective values can be used. Given the lack of non-warfighting simulations of military operations, the asset worth of the various components will probably have to be determined subjectively using some type of aggregation technique.

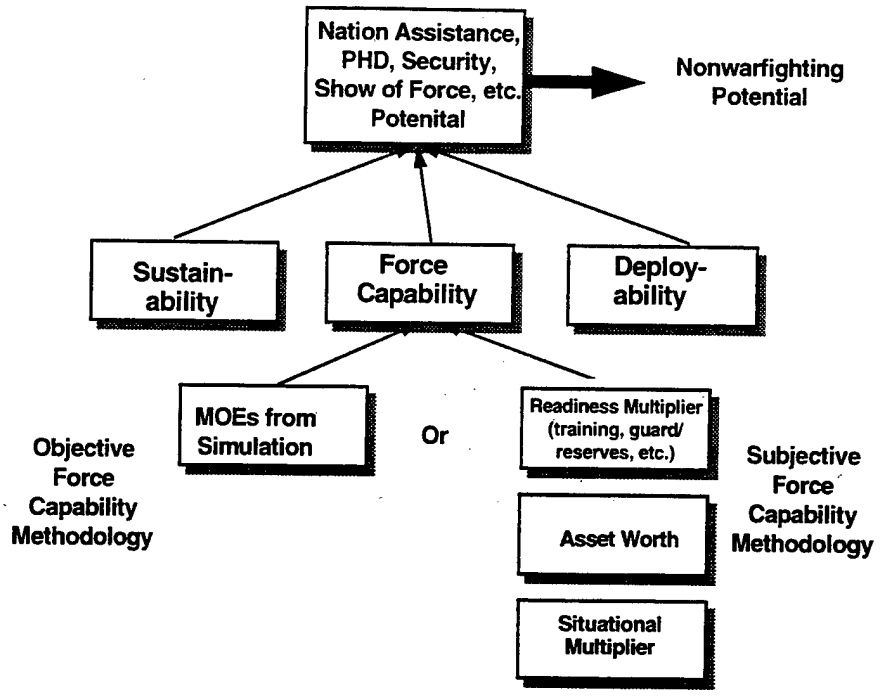

Figure 4.2 Methodology to determine non-warfighting potential calculations

Table 3.2 presents fifteen specific non-warfighting missions that have been grouped in five general mission categories. Table 3.3 presents some major MOEs to measure the capability of a particular MCP to perform a mission. Once the MOEs for a particular mission have been defined, the force structure derived from the warfighting IP can be used to determined to total force capability for that specific non-warfighting mission. This can be expressed mathematically as

$$NWP_j = \sum_{i=1}^{n} (MCP_i \, MOE_{ij}) \qquad (4.6)$$

where

NWP_j = non-warfighting potential for mission category j
MCP_i = mission capabilities package i
MOE_{ij} = measure of effectiveness for of mission capabilities package i conducting mission category j

Once the force structure has been determined from the warfighting analysis, the number of MCPs can be substituted into Equation 4.6--producing a

measure of non-warfighting capabilities. The using the warfighting sensitivity results, tradeoff analysis can then be performed between warfighting and non-warfighting force capabilities. Results similar to those presented in Figure 4.3 would be produced.

Option 1

MCP	Number of MCPs	War-fighting Potential	Nation Assistance Non-war-fighting Potential	PHD Non-war-fighting Potential	Security Non-war-fighting Potential	Show of Force Non-war-fighting Potential	Security Of Sea Lanes Non-war-fighting Potential
ADA	1	.340	.57	.33	.57	.43	0
LIDA	4	.548	.13	.42	.78	.41	0
"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"
DODSS	1	.001	0	0	0	0	0
Total	**NA**	**35.2**	**17.7**	**12.5**	**11.3**	**14.7**	**5.9**

Option 2

MCP	Number of MCPs	War-fighting Potential	Nation Assistance Non-war-fighting Potential	PHD Non-war-fighting Potential	Security Non-war-fighting Potential	Show of Force Non-war-fighting Potential	Security Of Sea Lanes Non-war-fighting Potential
ADA	2	.340	.57	.33	.57	.43	0
LIDA	3	.548	.13	.42	.78	.41	0
"	"	"	"	"	"	"	"
"	"	"	"	"	"	"	"
DODSS	1	.001	0	0	0	0	0
Total	**NA**	**33.2**	**16.7**	**11.5**	**10.3**	**15.7**	**5.9**

Figure 4.3 Tradeoff analysis of warfighting and non-warfighting missions

5. Example Study

5.1 Introduction

This chapter presents the results of an example study. This study was conducted only to demonstrate the methodology. Because of the limited duration and scope of this research (i.e., proof-of-principal demonstration) many approximations were used. Therefore, the results should not be construed as "study quality." Qualitatively accurate data was used when possible to ensure that the methodology will produce reasonable results.

The example study will present a comparison of alternatives notional force similar to that proposed under the present administration and a force structure developed using the IP methodology presented in Chapter 4. A comparison will be made using

- total combat potential (results of IP),
- total costs,
- and nation assistance potential.

as the significant MOEs. Table 5.1 shows this notional force structure in terms in MCPs.

5.2 Input Data

5.2.1 Warfighting Data

The first step is to develop the combat potential values to serve as objective function coefficients. As previously stated, the only way to definitively obtain a unit's combat potential is through combat simulation. However, for this example, static aggregate values are used because of their simplicity. The individual weapons systems scores or asset worth are shown in Table 5.2.[1] By summing the individual weapons in the various MCPs, the total asset worth for that unit can be determined (see Figure 4.1). Note that mobilization time and sustainability components will not be used for the example problem. The combat

[1]The values for land combat are based loosely on the land combat weapons scoring system developed by Rand; see Allen (1990). For naval ships, a similar land combat weapon system was simply mounted on a weapons platform (ship). For air assets, several static methods were reviewed. The ratios of the aircraft weapons score to some ground system from other static aggregation techniques were used to adjust the Rand values for the fixed wing aircraft. Some values were provided by Rand for rotary wing aircraft.

potential values for each MCP presented in Table 4.1 is presented in Table 5.3. Note that these are rough estimates used only for demonstration purposes. Table 5.4 summarizes the combat potential, costs, and personnel requirements for every MCP listed in Table 5.1. Many of these values are also rough estimates.

Table 5.1 Number and types of MCPs in the notional force structure

Mission Capabilities Package	Abbreviation	Category of MCP[1]	Number in Notional Force Structure[6]
Airborne Division Active	ADA	LCL	1
Light Infantry Division Active	LIDA	LCM	4
Armored Cavalry Regiment Active	ACRA	LCM	2
Marine Expeditionary Force Active[2]	MEFA	LCM	3
Air Assault Division Active	AADA	LCM	1
Separate Infantry Brigade Active	SIBA	LCM	1
Light Infantry Division Reserve	LIDR	LCM	1
Armored Cavalry Regiment Reserve	ACRR	LCM	1
Marine Expeditionary Force Reserve[3]	MEFR	LCM	2.5
Separate Infantry Brigade Reserve	SIBR	LCM	4
Heavy Division Active	HDA	LCH	4
Separate Heavy Brigade Active	SHBA	LCH	2
Heavy Division Reserve	HDR	LCH	1
Separate Heavy Brigade Reserve	SHBR	LCH	6
Carrier Battle Group	CBG	PP	11
Forward Deployable Aircraft Active[4]	FDA	PP	9
Surface Action Group Active	SAGA	PP	2
Forward Deployable Aircraft Reserve[5]	FDR	PP	11
Surface Action Group Reserve	SAGR	PP	3
Carrier Training Battle Group	CTBG	TR	1
Cadre Division	CD	TR	1
SOF - Navy Group Active	SOFNA	SOF	6
SOF - Army Group Active	SOFA	SOF	5
Ranger Battalions Active	RBA	SOF	3
SOF - Navy Group Reserve	SOFNR	SOF	6
SOF - Army Group Reserve	SOF	SOF	4
Attack Submarines Active	ASA	UW	40
Heavy Bomber Wing Active	HBA	LRAG	2
Recon, Intel, Elect War Wing Active	RIEWA	RIEW	2
Recon, Intel, Elect War Wing Reserve	RIEWR	RIEW	1

Table 5.1 continued

Unit Package	Abbreviation	Category of MCP[1]	Number in Notional Force Structure[6]
Mine Warfare Active	MWA	MW	16
Mine Warfare Reserve	MWR	MWPR	11
Anti Sub Fixed Wing Squad Active	ASWFA	AUW	6
Anti Sub Rotary Wing Squad Active	ASWRA	AUW	6
Anti Sub Fixed Wing Squad Reserve	ASWFR	AUW	3
Anti Sub Rotary Wing Squad Reserve	ASWRR	AUW	1
US Army Corps of Engineers	USACE	NA	1
US Coast Guard	USCG	NA	1
ICBM Missile Wings[7]	ICBMW	ND	1
Intelligence Agencies	IA	ND	1
DoD Space Commands	DODSC	SO	1
DoD Service Staffs	DODSS	ADMIN	1

1 See Table 3.1 or appendix A for description of the abbreviations
2 Includes 3 Marine Air Wings for close air support mission for the 9 brigades or 3 Marine Divisions.
3 Includes 1 Marine Air Wing for close air support mission.
4 This includes all Air Force Fighter Aircraft Wings (F15E and F16). All support, lift, and refueling assets are included with the units supported.
5 This includes all Air Force Fighter Aircraft Wings (F15E, F4G, and F16). All support, lift, and refueling assets are included with the units supported.
6 The numbers were estimated based upon limited information. Until the exact makeup of the various MCPs can be identified, the numbers cannot accurately be determined.
7 All six ICBM Wings are represented as 1 unit.

As shown in Figure 4.1, force capability using a subjective methodology has at least three components: readiness multiplier, asset worth, and other situational dependent multipliers. For the example problem, the only readiness multiplier used is 0.75 and will be applied to all land combat reserve units. Thus, the combat potential values that comprised the coefficients for the objective function will only be composed of a combat potential numbers with a readiness multiplier for land combat reserve units (see Figure 4.1). Air and sea assets were not adjusted by situational multipliers

Once the coefficients of the objective function have been determined, the next step is to determine the constraints for the problem. The constraints used for the example problem are shown in Table 5.5. These constraints are typical of those that might be used to shape a force structure. As discussed in Section 4.2.3, all constraints were divided into eight general areas.

Table 5.2 Individual weapons scores using static aggregates[1]

a. Air Force Weapons

Weapon	Asset Worth
Air Superiority - Active (F22,15E,16)	20
Air Superiority - Reserve (15E,16)	18
Close Air Support - Active (A10)	15
Close Air Support - Reserve (F10,4G)	12
Heavy Bomber Wings - Active (B52)	30
Heavy Bomber Wings - Reserve (B52)	30
Interdiction - Active (F111,117)	20
Interdiction - Reserve (F111,117)	20
Reconnaissance (RF4C)	0
Reconnaissance (RF4C)	0
Lift Wing - Active (C17,5,141,130)	0
Lift Wing Reserve (C5,141,130)	0
Tanker Wing - Active (KC10,135)	0
Tanker Wing - Reserve (KC10,135)	0

b. Navy and Marine Air

Weapon	Asset Worth
Air Superiority - Active (F/A-18,18D)	20
Air Superiority - Reserve (F/A-18,18D)	18
Air Superiority - Active (F4)	12
Air Superiority - Reserve (F4)	12
Heavy Bomber - Active (A-6)	13
Heavy Bomber - Reserve (A-6)	13
Attack Helicopters (AH-1 Cobra)	9
Air Superiority - Active (F14, F18)	20
Bomber - (A-6)	13
Sea Sparrow Missiles	3
20 mm CIWS	3
5/54 Mounts	6
5/38 Mounts	5
Anti Sub Rocket Launcher	8
Tartar Missile Launchers	8
50 cal MG	3
Tomahawk	3
Harpoon	2
SAM	2
MK-46 Torpedo	2
Torpedoes	2
Phalanx	2

[1] Same as asset worth values shown in Figure4.1.

Table 5.2 continued

c. Land Combat (Army and Marine)

Group	Weapon	Asset Worth
Mortar	SP81mm	1.2
Mortar	81mm	0.7
Mortar	60mm	0.4
Small Arms	Squad Auto Weapon - M249	0.2
Small Arm	Small Arms	0.15
Tanks	M1-A1	7.5
Tanks	M1	5.5
Tanks	M60-A3	3.5
Tanks	M60	2.5
IFV/AA	M2	3.5
APC	M113	0.8
LRAArm	Improved TOW/Vehicle	1.5
LRAArm	TOW/Mln-Vehicle	1.2
LRAArm	Imp TOW/MP	1.2
LRAArm	TOW/Mlnn-MP	0.9
SRAArm	Dragon	0.5
SRAArm	LAWs	0.2
SP Arty	203 MM Sp How	6
SP Arty	155 Hw Good	5
SP Arty	155 Hw Fair	4
SP Arty	SP Gun	3.5
SP Arty	122 Hw	2.7
SP Arty	100 Mortar	1.5
SP Arty	MLRS	10
SmArm	Small Arms	0.15
Td Arty	122 mm Gn/How	3
Td Arty	155 mm How	2.7
Td Arty	130 mm Gun	1.8
Td Arty	105 mm How	1.2
Td Arty	107+ mm MRL	2.5
At Helo	AH-64 (apache)	10
At Helo	AH-1S (Cobra)	9
At Helo	OH-58D (Kiowa)	3.5
Adef	20+ mm RAD ADA	1.5
Adef	57+mm ADA	1
Adef	20+mm SP ADA	1
Adef	20-40 mm Td ADA	0.7
Adef	AAMG	0.4
Adef	Chaparral	1.8
Adef	Stinger	1.3
Adef	Patriot	2.5
Adef	Vulcan	1.8

Table 5.3 Aggregated weapons scores used in combat potential values

Mission Capabilities Package	Category of MCP	Ground Combat Potential	Air Combat Potential	Sea Combat Potential	Total Asset Worth[1]
Airborne Division Active	LCL	1557	159	-	1716
Light Infantry Division Active	LCM	1603	1158	-	2761
Armored Cavalry Regiment Active	LCM	1371	1769	-	3140
Marine Expeditionary Force Active	LCM	647	1440	-	2087
Air Assault Division Active	LCM	1287	159	-	1547
Separate Infantry Brigade Active	LCM	1221	480	-	1701
Light Infantry Division Reserve	LCM	1069	1158	-	2271
Armored Cavalry Regiment Reserve	LCM	914	1769	-	2683
Marine Expeditionary Force Reserve	LCM	431	1440	-	1871
Separate Infantry Brigade Reserve	LCM	814	480	-	1294
Heavy Division Active	LCH	3960	1080	-	5040
Separate Heavy Brigade Active	LCH	1712	480	-	2192
Heavy Division Reserve	LCH	2640	1080	-	3720
Separate Heavy Brigade Reserve	LCH	1141	480	-	1621
Carrier Battle Group	PP	-	1020	1004	2024
Forward Deployable Aircraft Active	PP	-	1440	-	1440
Surface Action Group Active	PP	-	-	1004	1004
Forward Deployable Aircraft Reserve	PP	-	1440	-	1440
Surface Action Group Reserve	PP	-	-	1004	1004
Carrier Training Battle Group	TR	-	1020	1004	2024
Cadre Division	TR	730	-	-	730
SOF - Navy Group Active	SOF	100	50	-	150
SOF - Army Group Active	SOF	100	50	-	150
Ranger Battalion Active	SOF	150	100	-	250
SOF - Navy Group Reserve	SOF	50	50	-	100
SOF - Army Group Reserve	SOF	50	50	-	100
Attack Submarine Active	UW	-	-	72	72
Heavy Bomber Wing Active	LRAG	-	1350	-	1350
Recon, Intel, Elect War Wing Active	RIEW	-	225	-	225
Recon, Intel, Elect War Wing Reserve	RIEW	-	225	-	225

[1] These values are simply determined by multiplying the values in Table 4.2 by the corresponding number of that specific equipment type prescribed in the unit's tables of organization and equipment.

Table 5.3 continued

Mission Capabilities Package	Category of MCP	Ground	Air	Sea	Total Asset Worth
Mine Warfare Active	MW	-	-	50	50
Mine Warfare Reserve	MWPR	-	-	50	50
Anti Sub Fixed Wing Active	AUW	-	20	-	20
Anti Sub Rotary Wing Active	AUW	-	20	-	20
Anti Sub Fixed Wing Reserve	AUW	-	20	-	20
Anti Sub Rotary Wing Reserve	AUW	-	20	-	20
US Army Corps of Engineers	NA	-	-	-	1
US Coast Guard	NA	-	50	500	550
ICBM Missile Wings	ND	-	-	-	1
Intelligence Agencies	ND	-	-	-	1
DoD Space Commands	SO	-	-	-	1
DoD Service Staffs	ADMIN	-	-	-	1

Table 5.4 Combat potential and cost requirements for the various MCPs in the notionalforce structure

Mission Capabilities Package	Combat Potential	Costs (millions)	Percent Navy	Percent Army	Percent Air Force
Airborne Division Active	.340	4250	-	90	10
Light Infantry Division Active	.548	3750	-	90	10
Armored Cavalry Regiment Active	.623	2050	7	83	10
Marine Expeditionary Force Active	.414	3050	75	10	15
Air Assault Division Active	.307	3500	-	90	10
Separate Infantry Brigade Active	.338	1450	-	90	10
Light Infantry Division Reserve	.230	1275	-	90	10
Armored Cavalry Regiment Reserve	.532	1400	-	90	10
Marine Expeditionary Force Reserve	.371	1275	75	10	15
Separate Infantry Brigade Reserve	.257	900	-	90	10
Heavy Division Active	1.00	5000	5	75	20
Separate Heavy Brigade Active	.435	2400	5	75	20
Heavy Division Reserve	.738	3050	5	75	20
Separate Heavy Brigade Reserve	.322	1900	5	75	20
Carrier Battle Group	.401	4000	90	2	8
Forward Deployable Aircraft Active	.286	2350	-	-	100
Surface Action Group Active	.199	1000	95	-	5
Forward Deployable Aircraft Reserve	.286	1200	-	-	100
Surface Action Group Reserve	.199	700	95	-	5
Carrier Training Battle Group	.401	2300	95	2	3
Cadre Division	.145	2000	-	95	5
SOF - Navy Group Active	.030	230	70	25	5
SOF - Army Group Active	.030	230	-	75	25
Ranger Battalions Active	.049	520	-	80	20
SOF - Navy Group Reserve	.020	80	70	25	5
SOF - Army Group Reserve	.020	80	-	75	25
Attack Submarines Active	.014	250	100	-	-
Heavy Bomber Wing Active	.268	3000	-	-	100
Recon, Intel, Elect War Wing Active	.045	1800	-	25	75
Recon, Intel, Elect War Wing Reserve	.045	1027	-	25	75

Table 5.4 continued

Mission Capabilities Package	Combat Potential	Costs (millions)	Percent Navy	Percent Army	Percent Air Force
Mine Warfare Active	.010	200	100	-	-
Mine Warfare Reserve	.010	100	100	-	-
Anti Sub Fixed Wing Squad Active	.004	950	100	-	-
Anti Sub Rotary Wing Squad Active	.004	950	100	-	-
Anti Sub Fixed Wing Squad Reserve	.004	325	100	-	-
Anti Sub Rotary Wing Squad Reserve	.004	325	100	-	-
US Army Corps of Engineers	.001	4000	25	50	25
US Coast Guard	.109	2000	80	10	10
ICBM Missile Wings	.001	10000	33	33	34
Intelligence Agencies	.001	10000	34	33	33
DoD Space Commands	.001	2000	33	33	34
DoD Service Staffs	.001	2000	33	33	34

Table 5.5 Constraints used in joint force structure methodology

a. Operational-Active Requirements

- To respond to two simultaneous major regional conflicts (MRCs), at least 4-LCH (Division Equivalents), and 4-LCM (Division Equivalents) exclusive of the Marine Corp.
- The Army and Navy require at least 5 active groups and 6 active teams, respectively, to perform the various mission required by the SOF.
- At least 12 battle groups (either carrier of surface action) are required to perform security of sea lanes missions.
- The U.S. Navy must maintain at least 27 mine warfare ships with at least 6 active duty ships.
- For quick response and other missions, the Army must maintain at least one active duty Ranger Brigade.
- The DoD must maintain at least two RIEWA assets with at least one active duty unit.
- The U.S. Navy must maintain at least 16 anti submarine squadrons because of mission requirements with at least 6 active duty units.
- The U.S. Army must maintain at least 1-LCL for a quick response capability.
- In order to support the various land combat packages, 20 forward deployable aircraft wings are required with at least 10 active units.
- In order to support prepositioning of ground assets for quick response, the Army must maintain at least 1 air assault division.
- At least 40% of all ASW capabilities should be fixed wing aircraft for both active and reserve units.
- By law, the DoD is required to maintain at least 6 Marine Expeditionary Force Packages with at least 3 active duty units.

b. Operational-Reserve Requirements

- To respond to two simultaneous major regional conflicts (MRCs), at least 4-LCH (Division Equivalents) and 4-LCM (Division Equivalents) exclusive of the Marines.
- The Navy should maintain at least 1 carrier battle group in the reserves for training.
- Because of the need to preposition some Army assets, the Army must maintain at least 1 air assault division.
- The Army and Navy requires 4 reserve groups and 6 reserve teams, respectively, to perform the various mission required by the SOF.

Table 5.5 continued

c. Modern Force Requirements

- Over the last two decades, the U.S. Navy built six nuclear powered carriers. These carriers form the basis for a Carrier Battle Group and it is not economically feasible to decommission any of the ship.
- Over the last two decades, the U.S. Navy built forty nuclear powered submarines. In addition to performing an important strategic mission, it is not economically feasible to decommission any of the submarines nor build any additional ships.
- Only two Heavy Bomber Wings currently exist. Because of the minimum production rates set for the B-2 bomber, this number will not change.

d. Economic Requirements

- The total budget authority is available to support major warfighting units cannot exceed $90, 80, and 90 Billion for the Navy, Army, and Air Force Services.

e. Personnel Requirements

- The Army should staff and maintain 1 Cadre division in order to reduce active duty personnel.

f. Political Requirements

- Cannot increase the number of active Army Divisions from 12 as proposed under the previous administrations.
- Cannot increase the number of active and reserve Naval Carrier Battle groups from 15 as proposed under the previous administrations.
- Cannot increase the number of active and reserve forward deployable and heavy aircraft wings from 24 as proposed under the previous administrations.

f. Strategic Requirements

- The DoD must have the following agencies to support it's strategic mission: Nuclear Deterrence Package, Intelligence Agency Package, and Space Operations Package.

g. Support To The DoD

- The DoD must have the following indirect support agencies to perform its' mission: National Assistance Package and respective service staffs

As discussed in the introduction, three significant MOEs will be used for the study: total combat potential, total costs, and nation assistance potential. Total combat potential will be derived from the IP results. Also, using the costs shown in Table 5.4 combined with the results of the IP, the total costs can be determined for various force mixes. The last significant MOE will reflect a units capability to perform nation assistance.

5.2.2 Non-warfighting Data

Determination of a nation assistance MOE will require some assessment of a units capability to perform nation assistance. As shown in Table 2.3, two MOEs are proposed for nation assistance: horizontal and vertical construction capabilities. Table 5.6 presents a subjective assessment of the capabilities of various engineer equipment to perform horizontal construction. For this demonstration study vertical construction will not be included in the nation assistance MOE. Table 5.7 presents a summary of the nation assistance potential of the various MCPs. This value was determined by simply summing up the numbers of engineer equipment listing in the tables of organization and equipment (TOE) for a given MCP.

Table 5.6 Asset worth for nation assistance non-warfighting potential calculations

Equipment	Asset Worth
Armored Combat Excavator	0.5
Backhoe and Loader	0.7
Dump Truck	0.2
20 Ton Crane	0.2
Grader	0.5
Scoop Loader	0.6
D-7	1
Combat Engineer Vehicle	0.2
Scraper	0.7

Table 5.7 Nation assistance non-warfighting potential (NANP) for the various MCPs

Mission Capabilities Package	Force Capability	Normalized NANP
Airborne Division Active	26	.57
Light Infantry Division Active	6	.13
Armored Cavalry Regiment Active	10	.22
Marine Expeditionary Force Active	10	.22
Air Assault Division Active	14	.30
Separate Infantry Brigade Active	6	.13
Light Infantry Division Reserve	6	.13
Armored Cavalry Regiment Reserve	10	.22
Marine Expeditionary Force Reserve	10	.22
Separate Infantry Brigade Reserve	6	.13
Heavy Division Active	46	1.0
Separate Heavy Brigade Active	10	.22
Heavy Division Reserve	46	1.0
Separate Heavy Brigade Reserve	10	.22
Carrier Battle Group	0	0
Forward Deployable Aircraft Active	0	0
Surface Action Group Active	0	0
Forward Deployable Aircraft Reserve	0	0
Surface Action Group Reserve	0	0
Carrier Training Battle Group	0	0
Cadre Division	6	.13
SOF - Navy Group Active	0	0
SOF - Army Group Active	0	0
Ranger Battalions Active	6	.13
SOF - Navy Group Reserve	0	0
SOF - Army Group Reserve	0	0
Attack Submarines Active	0	0
Heavy Bomber Wing Active	0	0
Recon, Intel, Elect War Wing Active	0	0
Recon, Intel, Elect War Wing Reserve	0	0
Mine Warfare Active	0	0
Mine Warfare Reserve	0	0
Anti Sub Fixed Wing Squad Active	0	0
Anti Sub Rotary Wing Squad Active	0	0
Anti Sub Fixed Wing Squad Reserve	0	0
Anti Sub Rotary Wing Squad Reserve	0	0
US Army Corps of Engineers	0	0
US Coast Guard	0	0
ICBM Missile Wings	0	0
Intelligence Agencies	0	0
DoD Space Commands	0	0
DoD Service Staffs	0	0

5.3 Model Results

Obviously, any force structure can be "shaped" depending upon the constraints used for the IP model. Whether the IP generated force structure derived from the information and constraints contained in this chapter are realistic is irrelevant for this report. The purpose is to demonstrate the methodology and the advantages over other methods (mainly static aggregation techniques).

Tables 5.8 and 5.9 present a comparison of the notional and IP generated force structure mix and the significant MOEs (costs, construction, and total combat potential), respectively. The types of results contained in Table 5.9 are the main products of this type of analysis. Detailed model results are contained in Appendix B. The software package used to determine the IP solution and the results contained in Appendix B was the General Algebraic Modeling System (GAMS, see Kendrick et al., 1988). Microsoft Excel spreadsheets were used for pre-processing input data. Also, output can be easily be written to files using GAMS for post-processing. Based upon the results, new units could easily be inserted into the force mixes (i.e., armor with M1A2 versus the Block III tank) an the outcome on the performance be studied.

As shown in Table 5.9 an increase of roughly $18.8B was allowed. The GAMS models provides for simple modifications so that "what if" drills can easily be accomplished. Also contained in Appendix B are the results from another GAMS model. All of the constraints, objective function coefficients, etc., are the same with the exception all of the services budgets were cut $5B. Table 5.10 presents a comparison of the two IP solutions. Table 5.11 shows how this type of budget cut in the total budget authority (TBA) affects warfighting and non-warfighting capabilities.

Table 5.8 Notional force and IP generated force structure mix

Mission Capabilities Package	IP Generated Force Structure	Notional Force Structure
Airborne Division Active	1	1
Light Infantry Division Active	2	4
Armored Cavalry Regiment Active	0	2
Marine Expeditionary Force Active	3	3
Air Assault Division Active	1	1
Separate Infantry Brigade Active	3	1
Light Infantry Division Reserve	0	1
Armored Cavalry Regiment Reserve	10	1
Marine Expeditionary Force Reserve	10	2.5
Separate Infantry Brigade Reserve	4	4
Heavy Division Active	4	4
Separate Heavy Brigade Active	0	2
Heavy Division Reserve	6	1
Separate Heavy Brigade Reserve	0	6
Carrier Battle Group	6	11
Forward Deployable Aircraft Active	19	9
Surface Action Group Active	6	2
Forward Deployable Aircraft Reserve	1	11
Surface Action Group Reserve	10	3
Carrier Training Battle Group	1	1
Cadre Division	1	1
SOF - Navy Group Active	6	2
SOF - Army Group Active	1	5
Ranger Battalions Active	1	3
SOF - Navy Group Reserve	10	6
SOF - Army Group Reserve	20	4
Attack Submarines Active	40	40
Heavy Bomber Wing Active	2	2
Recon, Intel, Elect War Wing Active	1	2
Recon, Intel, Elect War Wing Reserve	1	1
Mine Warfare Active	17	16
Mine Warfare Reserve	10	11
Anti Sub Fixed Wing Squad Active	3	6
Anti Sub Rotary Wing Squad Active	3	6
Anti Sub Fixed Wing Squad Reserve	10	3
Anti Sub Rotary Wing Squad Reserve	0	1
US Army Corps of Engineers	1	1
US Coast Guard	1	1
ICBM Missile Wings	1	1
Intelligence Agencies	1	1
DoD Space Commands	1	1
DoD Service Staffs	1	1

Table 5.9 Summary of significant MOEs

MOE	Notional Force	IP Force	Percent Change
Combat Power Potential	28.8	36.8	+27.8
Construction Potential	11.3	17.4	+54.0
Costs (millions)	232,480	251,257	+8.1

The GAMS software has the capability to perform multiple runs. Thus, numerous runs could be performed to provide insight into how the force can be best optimize.

Table 5.10 IP generated force structure mix at two TBA

Mission Capabilities Package	Force Structure - $252.5B	Force Structure - $237.5B
Airborne Division Active	1	1
Light Infantry Division Active	2	2
Armored Cavalry Regiment Active	0	0
Marine Expeditionary Force Active	3	3
Air Assault Division Active	1	1
Separate Infantry Brigade Active	3	4
Light Infantry Division Reserve	0	0
Armored Cavalry Regiment Reserve	10	10
Marine Expeditionary Force Reserve	10	8
Separate Infantry Brigade Reserve	4	3
Heavy Division Active	4	4
Separate Heavy Brigade Active	0	0
Heavy Division Reserve	6	4
Separate Heavy Brigade Reserve	0	0
Carrier Battle Group	6	6
Forward Deployable Aircraft Active	19	17
Surface Action Group Active	6	6
Forward Deployable Aircraft Reserve	1	3
Surface Action Group Reserve	10	6
Carrier Training Battle Group	1	1
Cadre Division	1	1
SOF - Navy Group Active	6	6
SOF - Army Group Active	1	1
Ranger Battalions Active	1	1
SOF - Navy Group Reserve	10	8
SOF - Army Group Reserve	20	8
Attack Submarines Active	40	40
Heavy Bomber Wing Active	2	2
Recon, Intel, Elect War Wing Active	1	1
Recon, Intel, Elect War Wing Reserve	1	1
Mine Warfare Active	17	17
Mine Warfare Reserve	10	10
Anti Sub Fixed Wing Squad Active	3	3
Anti Sub Rotary Wing Squad Active	3	3
Anti Sub Fixed Wing Squad Reserve	10	10
Anti Sub Rotary Wing Squad Reserve	0	0
US Army Corps of Engineers	1	1
US Coast Guard	1	1
ICBM Missile Wings	1	1
Intelligence Agencies	1	1
DoD Space Commands	1	1
DoD Service Staffs	1	1

Table 5.11 Summary of significant MOEs for two TBA study

MOE	IP Force - $252.5	IP Force - $237.5	Percent Change
Combat Power Potential	36.8	33.6	- 8.7
Construction Potential	17.4	14.9	- 14.4
Costs (millions)	251,257	236,937	- 5.7

6. Summary and Conclusions

6.1 Summary

This research was directed at developing a methodology to assess joint force structure based upon warfighting requirements. Then using a similar methodology, assess the capabilities of that force structure to perform non-warfighting missions. In the past, joint force structure analysis has often been policy driven and lacking in detailed objective analytical support. The methodology presented was an attempt to develop a systematic procedure that will produce some insight into the force development process.

The warfighting methodology is based upon an IP to maximize the warfighting capabilities of the force structure. This warfighting capability has sustainability, deployability, and force capability components. If subjectively determined, the force capability component is comprised of an asset worth adjusted by a situational multiplier (function of terrain and type of battle) and readiness multiplier (function of training, cohesiveness, etc.). This force capability can be determined using results from a combat simulation model. Constraints for the linear program are divided into eight classes: economic, personnel, operational-active, operational-reserve, modern force, strategic, political, and support. These constraints are used to shape the force structure based upon security policy, strategic concerns, maximum warfighting capabilities, economic, etc., considerations.

The unit configurations that are an output of this analysis are termed MCPs. These packages are based upon the total force (Air Force, Army, Navy, and Marines) assets needed to accomplished a mission. For example, a land combat package-heavy might consist of a Army heavy division with units of combat and combat service support, Navy lift assets to get the units to theater, and Air Force close air support. These MCPs are proposed in order to more accurately ascertain the total costs to field a capability. Several types of a given MCP may exist to perform a certain mission.

Consistent with the philosophy of the DoD, the warfighting requirements determine the force structure. However, a similar methodology is used to determine the non-warfighting capabilities of a force structure. This non-warfighting potential has the same components as the combat potential (i.e., sustainability, force capability, and deployability). Five main categories of non-

warfighting missions are proposed: nation assistance; peacekeeping, humanitarian, and disaster; security; security of sea lanes, and show of force. For each of these categories, this potential function will be different and produce a value of force capability. Then, based upon historical analysis or simulation results, this value can be related to a typical non-warfighting mission capability.

Much of the input for the various potential functions is subjective. Additional research is need to validate the methodology and produce more defensible values for input.

An example problem is presented to demonstrate the methodology. When possible, the best available input was used to ensure the methodology would produce reasonable results. However, because of the limited duration of the research, rough estimates were often used for input. This example problem is presented only to demonstrate the methodology. The results contained herein should not be construed as study quality.

6.2 Conclusions

The methodology presented is an initial attempt to develop a force structure analysis process using MP. The demonstration study contained herein was performed simply as an early feasibility study. Before an actual study can be performed, several issues must be resolved. First, we must ensure that the costs can be ascertained for the various MCPs or reconfigure them such that costs can be assigned to the proper units. This will be the most difficult part of developing a working model. Also, a methodology for using combat models to determine combat potential must be developed in terms of MCPs. Lastly, MOEs must be developed for PHD, Security, Show of Force, and Security of Sea Lanes missions (i.e., all non-warfighting mission categories).

As the MAA process matures, the Resource Allocation Methodology (RAM) will also evolve. The next step in the evolution of the RAM will be a function of the MAA results. As shown in Figure 2.4, results from the Mission Effectiveness Assessment are combat and non-combat potentials and information used to develop the constraints. As proposed, the MAAs will produce these values and they will be priority weighted using the eigenvector method to produce sets of potential values for every MCP. Using this data, the RAM will probably evolve to a multi objective integer (or mixed integer) program. Also, an element that is typically not included in force structure analysis is basing

options. The ability support forces and then to project those forces (i.e., power projection platforms) is important in designing a force--especially when response time has becoming an important element of defense planning. With the lack of forward deployed bases, prepositioning of Army assets, etc., basing needs to be incorporated in the analysis.

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Appendix A. Acronyms and Abbreviations

Abbreviation	Description
AADA	Air Assault Division - Active Unit
ACRA	Armored Cavalry Regiment - Active Unit
ACRR	Armored Cavalry Regiment - Reserve Unit
ADA	Aiborne Divison - Active Unit
AP	Administrative Package
ASA	Attack Submarines
ASWFA	Anti Sub Fixed Wing Squad - Acitve Unit
ASWFR	Anti Sub Fixed Wing Squad - Reserve Unit
ASWRA	Anti Sub Rotary Wing Squad - Active Unit
ASWRR	Anti Sub Rotary Wing Squad - Reserve Unit
AUWPA	Anti Undersea Warfare Package - Acitve Units
AUWPR	Anti UNdersea Warfare Package - Reserve Units
BL	Blue Losses
CAA	U.S. Army Concepts Analysis Agency
CBG	Carrier Battle Group - Active Unit
CD	Cadre Division
CONUS	Conential United States
CP	Combat Potential
CTBG	Carrier Training Battle Group
DA	Department of the Army
DOD	Department of Defense
DODSC	DoD Space Commands
DODSS	DoD Service Staffs
DSE	Department of Systems Engineering
FC	Force Capability
FDA	Forward Deployable Aircraft - Active Unit
FDR	Forward Deployable Aircraft - Reserve Unit
FER	Force Exchange Ratio
FM	Field Manual
FMSP	Foreign Military Sales Program
HBA	Heavy Bomber Wing - Active Unit
HDA	Heavy Division - Active Unit
HDR	Heavy Division - Reserve Unit
IA	Intelligence Agenicies
IAP	Intelligence Agency Package
ICBMW	International Contential Ballistic Missile Wings
IP	Integer Program
IMETP	International Military Education and Training Program
LCPHA	Land Combat Package Heavy Active
LCPHR	Land Combat Package Heavy Reserve

Abbreviation	Description
LCPLA	Land Combat Package Light Active
LCPMA	Land Combat Package Medium Acitve Forces
LCPMR	Land Combat Pakcage Medium Reserve Forces
LIDA	Light Infantry Division - Active Unit
LIDR	Light Infantry Division - Reserve Unit
LRAGPA	Long Range Air-to-Ground Package Active Units
MCP	Mission Capabilites Package
MEFA	Marine Expeditionary Force - Active Unit
MEFR	Marine Expeditionary Force - Reserve Unit
MILP	Mixed Integer Linear Program
MOE	Measure of Effectiveness
MP	Mathematical Programming
MRC	Major Regional Conflict
MWA	Mine Warfare - Active Unit
MWPA	Mine Warfare Package - Active Units
MWPR	Mine Warfare Package - Reserve Units
MWR	Mine Warfare - Reserve Unit
NANWP	National Assistance Nonwarfighting Potential
NDP	Nuclear Deterrence Package
NWFC	Nonwarfighting Force Capability
ODPA&E	Office of the Secretary of Defense, Program Analysis and Evaluation
PHD	Peacekeeping, Humanitarin, and Diaster
POL	Petroleum, Oil, and Lubricants
POM	Project Objective Memorandum
PPPA	Power Projection Package - Active Units
PPPR	Power Projection Package - Reserve Units
RBA	Ranger Battalion - Active Unit
R&D	Research and Development
RHS	Right Hand Side
RIEPA	Recon, Intel, Elect War Package - Active Unit
RIEPR	Recon, Intel, Elect War Package - Reserve Units
RIEWA	Recon, Intel, Elect War Wing - Active Unit
RIEWR	Recon, Intel, Elect War Wing - Reserve Unit
SAGA	Surface Action Group - Active Unit
SAGR	Surface Action Group - Reserve Unit
SHBA	Separate Heavy Brigade - Active Units
SHBR	Separate Heavy Brigade - Reserve Units
SIBA	Separate Infatry Brigade - Active Unit

Abbreviation	Description
SIBR	Separate Infantry Brigade - Reserve Unit
SOF	Special Operation Forces
SOFA	Special Operations Force Package - Active Unit
SOFR	Special Operations Force Package - Reserve Unit
SOFAA	SOF - Active Army Group
SOFAR	SOF - Reserve Army Group
SOFNA	SOF - Active Navy Group
SOFNR	SOF - Reserve Navy Group
SOP	Space Operations Package
TASCFORM	Technique for Assessing Comparative Force Modenization
TBC	Time to Battle Completion
TOE	Tables of Organization and Equipment
TPA	Training Package - Active Units
UN	United Nations
USACE	U.S. Army Corps of Engineers
U.S.	United States
USCG	U.S. Coast Guard
USMA	U.S. Military Academy
UWPA	Undersea Warfare Package - Active Units
VAA	Value Added Analysis
V&V	Verfiication and Validation
WEI/WUV	Weapon Effectiveness Index/Weighted Unit Value

Appendix B. GAMS Implementation of RAM IP Model

```
INCLUDE    C:\FORCAM\SETS.TXT
  4  SETS
  5         MCP Mission Capabilities Package
  6         /
  7     ADA  Airborne Division Active
  8     LIDA Light Infantry Division Active
  9     ACRA Armored Cavalry Regiment Active
 10     MEFA Marine Expeditionary Force Active
 11     AADA Air Assault Division Active
 12     SIBA Separate Infantry Brigade Active
 13     LIDR Light Infantry Division Reserve
 14     ACRR Armored Cavalry Regiment Reserve
 15     MEFR Marine Expeditionary Force Reserve
 16     SIBR Separate Infantry Brigade Reserve
 17     HDA  Heavy Division  Active
 18     SHBA Separate Heavy Brigade Active
 19     HDR  Heavy Division Reserve
 20     SHBR Separate Heavy Brigade Reserve
 21     CBG  Carrier Battle Group
 22     FDA  Forward Deployable Aircraft Active
 23     SAGA Surface Action Group Active
 24     FDR  Forward Deployable Aircraft Reserve
 25     SAGR Surface Action Group Reserve
 26     CTBG Carrier Training Battle Group
 27     CD   Cadre Division
 28     SOFNA        SOF - Navy Group Active
 29     SOFA SOF - Army Group Active
 30     RBA  Ranger Battalions Active
 31     SOFNR        SOF - Navy Group Reserve
 32     SOF  SOF - Army Group  Reserve
 33     ASA  Attack Submarines  Active
 34     HBA  Heavy Bomber Wing Active
 35     RIEWA        Recon Intel Elect War Wing Active
 36     RIEWR        Recon Intel Elect War Wing Reserve
 37     MWA  Mine Warfare Active
 38     MWR  Mine Warfare Reserve
 39     ASWFA        Anti Sub Fixed Wing Squad Active
 40     ASWRA        Anti Sub Rotary Wing Squad Active
 41     ASWFR        Anti Sub Fixed Wing Squad Reserve
 42     ASWRR        Anti Sub Rotary Wing Squad Reserve
 43     USACE        US Army Corps of Engineers
 44     USCG US Coast Guard
 45     ICBMW        ICBM Missile Wings
 46     IA   Intelligence Agencies
 47     DODSC        DoD Space Commands
 48     DODSS        DoD Service Staffs
 49         /
 50  HEA(MCP)        Heavy Division Equivalents-Active  / HDA, SHBA/
 51  MEA(MCP)        Medium Division Equivalents-Active / LIDA, ACRA, AADA,
                                                          SIBA /
 52  CSBG(MCP)       Surface or Carrier Battle Groups   / SAGA, CBG /
 53  MW(MCP)         Mine Warfare Ships   / MWA, MWR /
 54  RW(MCP)         Recon-Intel-Elec War Wings  / RIEWA, RIEWR /
```



```
 55  AS(MCP)         Anti-submarine Squadrons    / ASWFA, ASWRA, ASWFR, ASWRR /
 56  ASA(MCP)        Anti-submarine Squadrons Active    / ASWFA, ASWRA /
 57  ASR(MCP)        Anti-submarine Squadrons Reserve   / ASWFR, ASWRR /
 58  ME(MCP)         Marine Expeditionary Forces / MEFA, MEFR /
 59  HER(MCP)        Heavy Division Equivalents-Reserve / HDR, SHBR/
 60  MER(MCP)        Medium Division Equivalents-Reserve       / LIDR, ACRR,
                                                                 SIBR /
 61  AD(MCP)         Active Army Divisions       / ADA, LIDA, AADA, HDA /
 62  BG(MCP)         Carrier Battle Groups       / CBG, CTBG /
 63  TOTAW(MCP)      Total Number of Aircraft Wings / FDA, FDR, HBA, RIEWA,
                                                                 RIEWR /
 64  FW(MCP)         Forward Deploy Aircraft Wings / FDA, FDR /
 65          ;
INCLUDE    C:\FORCAM\CP.TXT
 67  Table Data(MCP,*)
 68
 69          LOW     UP      ComPot  Cost    Navy    Army    AirF    NANP    ForEq
 70  ADA     1       10      0.34    4250            0.9     0.1     0.57    1
 71  LIDA    2       10      0.548   3750            0.9     0.1     0.13    1
 72  ACRA    0       10      0.623   2050    0.7     0.83    0.1     0.22
                                                                     0.33333333333333
 73  MEFA    3       10      0.414   3050    0.75    0.1     0.15    0.22    1
 74  AADA    1       10      0.307   3500            0.9     0.1     0.3     1
 75  SIBA    0       10      0.338   1450            0.9     0.1     0.13
                                                                     0.33333333333333
 76  LIDR    0       10      0.23    1275            0.9     0.1     0.13    1
 77  ACRR    0       10      0.532   1400            0.9     0.1     0.22
                                                                     0.33333333333333
 78  MEFR    0       10      0.371   1275    0.75    0.1     0.15    0.22    1
 79  SIBR    0       10      0.257   900             0.9     0.1     0.13
                                                                     0.33333333333333
 80  HDA     0       10      1       5000    0.05    0.75    0.2     1       1
 81  SHBA    0       10      0.435   2400    0.05    0.75    0.2     0.22
                                                                     0.33333333333333
 82  HDR     0       10      0.738   3050    0.05    0.75    0.2     1       1
 83  SHBR    0       10      0.322   1900    0.05    0.75    0.2     0.22
                                                                     0.33333333333333
 84  CBG     6       10      0.401   4000    0.9     0.02    0.08            1
 85  FDA     10      30      0.286   2350                    1
 86  SAGA    0       10      0.199   1000    0.95            0.05            1
 87  FDR     0       10      0.286   1200                    1
 88  SAGR    0       10      0.199   700     0.95            0.05
 89  CTBG    1       10      0.401   2300    0.95    0.02    0.03
 90  CD      1       10      0.145   2000            0.95    0.05    0.13
 91  SOFNA   6       20      0.03    230     0.7     0.25    0.05
 92  SOFA    1       10      0.03    230             0.75    0.25
 93  RBA     1       10      0.049   520             0.8     0.2     0.13
 94  SOFNR   6       10      0.02    80      0.7     0.25    0.05
 95  SOF     4       20      0.02    80              0.75    0.25
 96  ASA     40      60      0.014   250     1
 97  HBA     2       10      0.268   3000                    1
 98  RIEWA   1       10      0.045   1800            0.25    0.75            1
 99  RIEWR   0       10      0.045   1027            0.25    0.75            1
```

```
100  MWA     6       40      0.01    200     1                               1
101  MWR     0       10      0.01    100     1                               1
102  ASWFA   0       10      0.004   950     1                               1
103  ASWRA   0       10      0.004   950     1                               1
104  ASWFR   0       10      0.004   325     1                               1
105  ASWRR   0       10      0.004   325     1                               1
106  USACE   1       10      0.001   4000    0.25    0.5     0.25
107  USCG    1       10      0.109   2000    0.8     0.1     0.1
108  ICBMW   1       10      0.001   10000   0.33    0.33    0.34
109  IA      1       10      0.001   10000   0.34    0.33    0.33
110  DODSC   1       10      0.001   2000    0.33    0.33    0.34
111  DODSS   1       10      0.001   2000    0.33    0.33    0.34
112  OPTIONS OPTCR=0.01, OPTCA=0.5 ;
113  PARAMETERS
114         CP(MCP)         Combat Potential for each Mission Capabilities
                                                                      Package
115         FB(MCP) Mission Capabilities Equivalency Ratio
116         COST(MCP) Total Cost for Mission Capability Package
117         PERARMY(MCP) Percent of Mission Capability Package Comprised of
                                                                    Army Forces
118         PERNAVY(MCP) Percent of Mission Capability Package Comprised of
                                                                    Naval Forces
119         PERAIRF(MCP) Percent of Mission Capability Package Comprised of
                                                                      Air Forces
120         ;
121
122  CP(MCP)=DATA(MCP,'COMPOT') ;
123  FB(MCP)=DATA(MCP,'FOREQ') ;
124  COST(MCP)=DATA(MCP,'COST') ;
125  PERARMY(MCP)=DATA(MCP,'ARMY') ;
126  PERNAVY(MCP)=DATA(MCP,'NAVY') ;
127  PERAIRF(MCP)=DATA(MCP,'AIRF') ;
128
129  VARIABLES
130         X(MCP) Number of Mission Capabilities Packages required in force
131         TFPOT  Total force combat potential
132         ;
133  INTEGER VARIABLES X(MCP) ;
134  X.LO(MCP)=DATA(MCP,'LOW') ;
135  X.UP(MCP)=DATA(MCP,'UP') ;
136
137  EQUATIONS
138         COMBAT Total combat potential of MCP's in force
139  *      OPNSREQ         Operational Force Requirements
140  *      MODREQ Modern Force Requirements
141  *      ECONREQ         Economic Requirements
142  *      PERREQ Personnel Requirements
143  *      POLREQ Political Requirements
144  *      STGYREQ         Strategic Requirments
145  *      DODREQ DOD Support Requirements
146
147         AHDREQ Operational Requirements for Active Heavy Divisions
148         AMDREQ Operational Requirements for Active Medium Divisions
```



```
149         CBGREQ Operational Requirements for Surface or Carrier Battle
                                                                      Groups
150         MWREQ  Operational Requirements for Mine Warfare Ships
151         RIEWREQ         Operational Requirements for RIEW assets
152         ASWREQ Operational Requirements for ASW assets
153         ASAWREQ         Operational Requirements for active ASW assets
154         ASWARAT         Require at least 40% of all Active ASW is Fixed Wing
155         ASWRRAT         Require at least 40% of all Reserve ASW is Fixed
                                                                        Wing
156         MEFREQ  Operational Requirements for Marine Expeditionary Forces
157         RHDREQ Operational Requirements for Reserve Heavy Divisions
158         RMDREQ Operational Requirements for Reserve Medium Divisions
159         ARMYBUD         Budget Authority for Army Forces
160         AFBUD  Budget Authority for Air Force Service
161         NAVYBUD         Budget Authority for Naval Forces
162         TAAD   Political Requirements for no more than 12 Active Army
                                                                    Divisions
163         TBG    Political Requirements for no more than 15 Carrier Battle
                                                                      Groups
164         TAWREQ Political Requirements for no more than 24 Forward Dep and
                                                                  Heavy Wings
165         FDAWREQ         Operational Requirements for Forward Deployable
                                                                  Aircraft Wings
166
167         ;
168
169  COMBAT .. SUM(MCP, X(MCP)*CP(MCP)) =E= TFPOT ;
170
171  AHDREQ .. SUM(HEA, X(HEA)*FB(HEA)) =G= 4 ;
172
173  AMDREQ .. SUM(MEA, X(MEA)*FB(MEA)) =G= 4 ;
174
175  CBGREQ .. SUM(CSBG, X(CSBG)*FB(CSBG)) =G= 12 ;
176
177  MWREQ ..  SUM(MW, X(MW)*FB(MW)) =G= 27;
178
179  RIEWREQ .. SUM(RW, X(RW)*FB(RW)) =G= 2 ;
180
181  ASWREQ .. SUM(AS, X(AS)*FB(AS)) =G= 16 ;
182
183         ASWARAT .. 0.6*X("ASWFA")-0.4*X("ASWRA") =G= 0.4 ;
184
185         ASWRRAT .. 0.6*X("ASWFR")-0.4*X("ASWRR") =G= 0.4 ;
186
187  ASAWREQ .. SUM(ASA, X(ASA)) =G= 6 ;
188
189  MEFREQ .. SUM(ME, X(ME)*FB(ME)) =G= 6 ;
190
191  RHDREQ .. SUM(HER, X(HER)*FB(HER)) =G= 4 ;
192
193  RMDREQ .. SUM(MER, X(MER)*FB(MER)) =G= 4 ;
194
195  ARMYBUD .. SUM(MCP$DATA(MCP,"ARMY"), X(MCP)*COST(MCP)*PERARMY(MCP)) =L=
```

```
                                                                    80000 ;
196
197  AFBUD .. SUM(MCP$DATA(MCP,"AIRF"), X(MCP)*COST(MCP)*PERAIRF(MCP)) =L=
                                                                    82500 ;
198
199  NAVYBUD .. SUM(MCP$DATA(MCP,"NAVY"), X(MCP)*COST(MCP)*PERNAVY(MCP)) =L=
                                                                    90000 ;
200
201  TAAD .. SUM(AD, X(AD)) =L= 12 ;
202
203  TBG .. SUM(BG, X(BG)) =L= 15 ;
204
205  TAWREQ .. SUM(TOTAW, X(TOTAW)) =L= 24 ;
206
207  FDAWREQ .. SUM(FW, X(FW)) =G= 20 ;
208
209  *MODEL TFRAM / ALL /
210  MODEL TFRAM / COMBAT, AHDREQ, AMDREQ, CBGREQ, MWREQ, RIEWREQ, ASWREQ,
                                                          ASAWREQ, ASWARAT,
211           ASWRRAT, MEFREQ, RHDREQ, ARMYBUD, AFBUD, NAVYBUD, RMDREQ, TAAD,
                                                     TBG, TAWREQ, FDAWREQ /
212  *MODEL TFRAM / COMBAT, AHDREQ, AMDREQ, CBGREQ, MWREQ, RIEWREQ, ASWREQ,
                                                   ASAWREQ, ASWARAT, ASWRRAT,
213  *       MEFREQ, RHDREQ, RMDREQ, ARMYBUD, AFBUD, NAVYBUD, TAAD, TBG,
                                                     TAWREQ, FDAWREQ /
214
215  SOLVE TFRAM USING MIP MAXIMIZING TFPOT;
216
217  PARAMETER REPORT1 Total Cost of the Proposed Force Structure ;
218  PARAMETER REPORT2 Total Combat Power of the Proposed Force Structure ;
219  PARAMETER REPORT3 Total Non-Warfighting Potential of the Proposed Force
                                                            Structure ;
220
221  REPORT1 = SUM(MCP$DATA(MCP,"ARMY"), X.L(MCP)*COST(MCP)*PERARMY(MCP)) +
222           SUM(MCP$DATA(MCP,"AIRF"), X.L(MCP)*COST(MCP)*PERAIRF(MCP)) +
223           SUM(MCP$DATA(MCP,"NAVY"), X.L(MCP)*COST(MCP)*PERNAVY(MCP)) ;
224
225  REPORT2 = TFPOT.L ;
226
227  REPORT3 = SUM(MCP, X.L(MCP)*DATA(MCP,"NANP")) ;
228
229  DISPLAY REPORT1, REPORT2, REPORT3;
```


GLOBAL	TYPE	LOCAL	FILE NAME
0	INPUT	0	C:\FORCAM\TFRAM.GMS
3	INCLUDE	3	.C:\FORCAM\SETS.TXT
66	INCLUDE	4	.C:\FORCAM\CP.TXT

COMPILATION TIME = 1.100 SECONDS VERID MW2-25-069

---- COMBAT =E= Total combat potential of MCP's in force

COMBAT.. 0.34*X(ADA) + 0.548*X(LIDA) + 0.623*X(ACRA) + 0.414*X(MEFA)
+ 0.307*X(AADA) + 0.338*X(SIBA) + 0.23*X(LIDR) + 0.532*X(ACRR)
+ 0.371*X(MEFR) + 0.257*X(SIBR) + X(HDA) + 0.435*X(SHBA) + 0.738*X(HDR)
+ 0.322*X(SHBR) + 0.401*X(CBG) + 0.286*X(FDA) + 0.199*X(SAGA)
+ 0.286*X(FDR) + 0.199*X(SAGR) + 0.401*X(CTBG) + 0.145*X(CD)
+ 0.03*X(SOFNA) + 0.03*X(SOFA) + 0.049*X(RBA) + 0.02*X(SOFNR)
+ 0.02*X(SOF) + 0.014*X(ASA) + 0.268*X(HBA) + 0.045*X(RIEWA)
+ 0.045*X(RIEWR) + 0.01*X(MWA) + 0.01*X(MWR) + 0.004*X(ASWFA)
+ 0.004*X(ASWRA) + 0.004*X(ASWFR) + 0.004*X(ASWRR) + 0.001*X(USACE)
+ 0.109*X(USCG) + 0.001*X(ICBMW) + 0.001*X(IA) + 0.001*X(DODSC)
+ 0.001*X(DODSS) - TFPOT =E= 0 ; (LHS = 10.571 ***)

---- AHDREQ =G= Operational Requirements for Active Heavy Divisions

AHDREQ.. X(HDA) + 0.3333*X(SHBA) =G= 4 ; (LHS = 0 ***)

---- AMDREQ =G= Operational Requirements for Active Medium Divisions

AMDREQ.. X(LIDA) + 0.3333*X(ACRA) + X(AADA) + 0.3333*X(SIBA) =G= 4 ;
(LHS = 3 ***)

---- CBGREQ =G= Operational Requirements for Surface or Carrier Battle Groups

CBGREQ.. X(CBG) + X(SAGA) =G= 12 ; (LHS = 6 ***)

---- MWREQ =G= Operational Requirements for Mine Warfare Ships

MWREQ.. X(MWA) + X(MWR) =G= 27 ; (LHS = 6 ***)

---- RIEWREQ =G= Operational Requirements for RIEW assets

RIEWREQ.. X(RIEWA) + X(RIEWR) =G= 2 ; (LHS = 1 ***)

---- ASWREQ =G= Operational Requirements for ASW assets

ASWREQ.. X(ASWFA) + X(ASWRA) + X(ASWFR) + X(ASWRR) =G= 16 ; (LHS = 0 ***)

---- ASAWREQ =G= Operational Requirements for active ASW assets

ASAWREQ.. X(ASWFA) + X(ASWRA) =G= 6 ; (LHS = 0 ***)

---- ASWARAT =G= Require at least 40% of all Active ASW is Fixed Wing

ASWARAT.. 0.6*X(ASWFA) - 0.4*X(ASWRA) =G= 0.4 ; (LHS = 0 ***)

---- ASWRRAT =G= Require at least 40% of all Reserve ASW is Fixed Wing

ASWRRAT.. 0.6*X(ASWFR) - 0.4*X(ASWRR) =G= 0.4 ; (LHS = 0 ***)

---- MEFREQ =G= Operational Requirements for Marine Expeditionary Forces

MEFREQ.. X(MEFA) + X(MEFR) =G= 6 ; (LHS = 3 ***)

---- RHDREQ =G= Operational Requirements for Reserve Heavy Divisions

RHDREQ.. X(HDR) + 0.3333*X(SHBR) =G= 4 ; (LHS = 0 ***)

---- ARMYBUD =L= Budget Authority for Army Forces

ARMYBUD.. 3825*X(ADA) + 3375*X(LIDA) + 1701.5*X(ACRA) + 305*X(MEFA)
+ 3150*X(AADA) + 1305*X(SIBA) + 1147.5*X(LIDR) + 1260*X(ACRR)
+ 127.5*X(MEFR) + 810*X(SIBR) + 3750*X(HDA) + 1800*X(SHBA)
+ 2287.5*X(HDR) + 1425*X(SHBR) + 80*X(CBG) + 46*X(CTBG) + 1900*X(CD)
+ 57.5*X(SOFNA) + 172.5*X(SOFA) + 416*X(RBA) + 20*X(SOFNR) + 60*X(SOF)
+ 450*X(RIEWA) + 256.75*X(RIEWR) + 2000*X(USACE) + 200*X(USCG)
+ 3300*X(ICBMW) + 3300*X(IA) + 660*X(DODSC) + 660*X(DODSS) =L= 80000 ;
(LHS = 28929.5)

---- AFBUD =L= Budget Authority for Air Force Service

AFBUD.. 425*X(ADA) + 375*X(LIDA) + 205*X(ACRA) + 457.5*X(MEFA) + 350*X(AADA)
+ 145*X(SIBA) + 127.5*X(LIDR) + 140*X(ACRR) + 191.25*X(MEFR)
+ 90*X(SIBR) + 1000*X(HDA) + 480*X(SHBA) + 610*X(HDR) + 380*X(SHBR)
+ 320*X(CBG) + 2350*X(FDA) + 50*X(SAGA) + 1200*X(FDR) + 35*X(SAGR)
+ 69*X(CTBG) + 100*X(CD) + 11.5*X(SOFNA) + 57.5*X(SOFA) + 104*X(RBA)
+ 4*X(SOFNR) + 20*X(SOF) + 3000*X(HBA) + 1350*X(RIEWA)
+ 770.25*X(RIEWR) + 1000*X(USACE) + 200*X(USCG) + 3400*X(ICBMW)
+ 3300*X(IA) + 680*X(DODSC) + 680*X(DODSS) =L= 82500 ; (LHS = 45431)

---- NAVYBUD =L= Budget Authority for Naval Forces

NAVYBUD.. 1435*X(ACRA) + 2287.5*X(MEFA) + 956.25*X(MEFR) + 250*X(HDA)
+ 120*X(SHBA) + 152.5*X(HDR) + 95*X(SHBR) + 3600*X(CBG) + 950*X(SAGA)
+ 665*X(SAGR) + 2185*X(CTBG) + 161*X(SOFNA) + 56*X(SOFNR) + 250*X(ASA)
+ 200*X(MWA) + 100*X(MWR) + 950*X(ASWFA) + 950*X(ASWRA) + 325*X(ASWFR)
+ 325*X(ASWRR) + 1000*X(USACE) + 1600*X(USCG) + 3300*X(ICBMW)

NAVYBUD =L= Budget Authority for Naval Forces

+ 3400*X(IA) + 660*X(DODSC) + 660*X(DODSS) =L= 90000 ; (LHS = 53769.5)

---- RMDREQ =G= Operational Requirements for Reserve Medium Divisions

RMDREQ.. X(LIDR) + 0.3333*X(ACRR) + 0.3333*X(SIBR) =G= 4 ; (LHS = 0 ***)

---- TAAD =L= Political Requirements for no more than 12 Active Army Divisions

TAAD.. X(ADA) + X(LIDA) + X(AADA) + X(HDA) =L= 12 ; (LHS = 4)

---- TBG =L= Political Requirements for no more than 15 Carrier Battle Groups

TBG.. X(CBG) + X(CTBG) =L= 15 ; (LHS = 7)

---- TAWREQ =L= Political Requirements for no more than 24 Forward Dep and Heavy Wings

TAWREQ.. X(FDA) + X(FDR) + X(HBA) + X(RIEWA) + X(RIEWR) =L= 24 ; (LHS = 13)

---- FDAWREQ =G= Operational Requirements for Forward Deployable Aircraft Wings

FDAWREQ.. X(FDA) + X(FDR) =G= 20 ; (LHS = 10 ***)

---- X Number of Mission Capabilities Packages required in force

X(ADA)

(.LO, .L, .UP = 1, 1, 10)

0.34	COMBAT
3825	ARMYBUD
425	AFBUD
1	TAAD

X(LIDA)

(.LO, .L, .UP = 2, 2, 10)

0.548	COMBAT
1	AMDREQ
3375	ARMYBUD
375	AFBUD
1	TAAD

X(ACRA)

(.LO, .L, .UP = 0, 0, 10)

0.623	COMBAT
0.3333	AMDREQ
1701.5	ARMYBUD
205	AFBUD
1435	NAVYBUD

REMAINING 39 ENTRIES SKIPPED

---- TFPOT Total force combat potential

TFPOT

(.LO, .L, .UP = -INF, 0, +INF)

-1	COMBAT

MODEL STATISTICS

BLOCKS OF EQUATIONS	20	SINGLE EQUATIONS	20
BLOCKS OF VARIABLES	2	SINGLE VARIABLES	43
NON ZERO ELEMENTS	176	DISCRETE VARIABLES	42

GENERATION TIME = 0.990 SECONDS

EXECUTION TIME = 1.370 SECONDS VERID MW2-25-069

S O L V E S U M M A R Y

MODEL	TFRAM	OBJECTIVE	TFPOT
TYPE	MIP	DIRECTION	MAXIMIZE
SOLVER	OSL	FROM LINE	215

**** SOLVER STATUS 1 NORMAL COMPLETION
**** MODEL STATUS 8 INTEGER SOLUTION
**** OBJECTIVE VALUE 36.8340

RESOURCE USAGE, LIMIT 29.108 1000.000
ITERATION COUNT, LIMIT 664 1000

OSL Release 2, GAMS Link level 3 --- 386/486 DPMI 1.3.045-020

Work space allocated -- .21 Mb

Relaxed optimum objective value: 36.885487
Bound on best integer solution: 36.842196
Objective value of this solution: 36.834000

Relative gap: .00022 Absolute gap: 8.19633030E-03
Optcr : .01000 Optca: .50000000

The solution satisfies the termination tolerances

	LOWER	LEVEL	UPPER	MARGINAL
---- EQU COMBAT	.	.	.	-1.000
---- EQU AHDREQ	4.000	4.000	+INF	.
---- EQU AMDREQ	4.000	4.000	+INF	.
---- EQU CBGREQ	12.000	12.000	+INF	.
---- EQU MWREQ	27.000	27.000	+INF	.
---- EQU RIEWREQ	2.000	2.000	+INF	-0.241
---- EQU ASWREQ	16.000	16.000	+INF	.
---- EQU ASAWREQ	6.000	6.000	+INF	.
---- EQU ASWARAT	0.400	0.600	+INF	.
---- EQU ASWRRAT	0.400	6.000	+INF	.
---- EQU MEFREQ	6.000	13.000	+INF	.
---- EQU RHDREQ	4.000	6.000	+INF	.
---- EQU ARMYBUD	-INF	79981.250	80000.000	.
---- EQU AFBUD	-INF	81304.750	82500.000	.
---- EQU NAVYBUD	-INF	89971.000	90000.000	.
---- EQU RMDREQ	4.000	4.667	+INF	.
---- EQU TAAD	-INF	8.000	12.000	.
---- EQU TBG	-INF	7.000	15.000	.
---- EQU TAWREQ	-INF	24.000	24.000	0.286
---- EQU FDAWREQ	20.000	20.000	+INF	.

COMBAT	Total combat potential of MCP's in force
AHDREQ	Operational Requirements for Active Heavy Divisions

AMDREQ	Operational Requirements for Active Medium Divisions
CBGREQ	Operational Requirements for Surface or Carrier Battle Groups
MWREQ	Operational Requirements for Mine Warfare Ships
RIEWREQ	Operational Requirements for RIEW assets
ASWREQ	Operational Requirements for ASW assets
ASAWREQ	Operational Requirements for active ASW assets
ASWARAT	Require at least 40% of all Active ASW is Fixed Wing
ASWRRAT	Require at least 40% of all Reserve ASW is Fixed Wing
MEFREQ	Operational Requirements for Marine Expeditionary Forces
RHDREQ	Operational Requirements for Reserve Heavy Divisions
ARMYBUD	Budget Authority for Army Forces
AFBUD	Budget Authority for Air Force Service
NAVYBUD	Budget Authority for Naval Forces
RMDREQ	Operational Requirements for Reserve Medium Divisions
TAAD	Political Requirements for no more than 12 Active Army Divisions
TBG	Political Requirements for no more than 15 Carrier Battle Groups
TAWREQ	Political Requirements for no more than 24 Forward Dep and Heavy Wings
FDAWREQ	Operational Requirements for Forward Deployable Aircraft Wings

---- VAR X Number of Mission Capabilities Packages required in force

	LOWER	LEVEL	UPPER	MARGINAL
ADA	1.000	1.000	10.000	0.340
LIDA	2.000	2.000	10.000	0.548
ACRA	.	.	10.000	0.623
MEFA	3.000	3.000	10.000	0.414
AADA	1.000	1.000	10.000	0.307
SIBA	.	3.000	10.000	0.338
LIDR	.	.	10.000	0.230
ACRR	.	10.000	10.000	0.532
MEFR	.	10.000	10.000	0.371
SIBR	.	4.000	10.000	0.257
HDA	.	4.000	10.000	1.000
SHBA	.	.	10.000	0.435
HDR	.	6.000	10.000	0.738
SHBR	.	.	10.000	0.322
CBG	6.000	6.000	10.000	0.401
FDA	10.000	19.000	30.000	EPS
SAGA	.	6.000	10.000	0.199
FDR	.	1.000	10.000	EPS
SAGR	.	10.000	10.000	0.199
CTBG	1.000	1.000	10.000	0.401
CD	1.000	1.000	10.000	0.145
SOFNA	6.000	6.000	20.000	0.030
SOFA	1.000	1.000	10.000	0.030
RBA	1.000	1.000	10.000	0.049
SOFNR	6.000	10.000	10.000	0.020
SOF	4.000	20.000	20.000	0.020
ASA	40.000	40.000	60.000	0.014
HBA	2.000	2.000	10.000	-0.018

VAR X Number of Mission Capabilities Packages required in force

	LOWER	LEVEL	UPPER	MARGINAL
RIEWA	1.000	1.000	10.000	EPS
RIEWR	.	1.000	10.000	EPS
MWA	6.000	17.000	40.000	0.010
MWR	.	10.000	10.000	0.010
ASWFA	.	3.000	10.000	0.004
ASWRA	.	3.000	10.000	0.004
ASWFR	.	10.000	10.000	0.004
ASWRR	.	.	10.000	0.004
USACE	1.000	1.000	10.000	0.001
USCG	1.000	1.000	10.000	0.109
ICBMW	1.000	1.000	10.000	0.001
IA	1.000	1.000	10.000	0.001
DODSC	1.000	1.000	10.000	0.001
DODSS	1.000	1.000	10.000	0.001

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR TFPOT	-INF	36.834	+INF	.

TFPOT Total force combat potential

**** REPORT SUMMARY : 0 NONOPT
0 INFEASIBLE
0 UNBOUNDED

---- 229 PARAMETER REPORT1 = 251257.000 Total Cost of the Proposed Force Structure

PARAMETER REPORT2 = 36.834 Total Combat Power of the Proposed Force Structure

PARAMETER REPORT3 = 17.360 Total Non-Warfighting Potential of the Proposed Force Structure

EXECUTION TIME = 0.760 SECONDS VERID MW2-25-069

USER: Dr. John Farr B940429-1026Ax-MW2
Dept. of Systems Engineering, U.S. Military Academy

**** FILE SUMMARY

INPUT C:\FORCAM\TFRAM.GMS
OUTPUT C:\GAMS\TFRAM.LST

Case 2: Reduced Budget

```
 GAMS 2.25.069  386/486 DOS                          05/13/94 14:14:09  PAGE
12
TOTAL FORCE RESOURCE ALLOCATION MODEL
Model Statistics     SOLVE TFRAM USING MIP FROM LINE 215


MODEL STATISTICS

BLOCKS OF EQUATIONS       20     SINGLE EQUATIONS        20
BLOCKS OF VARIABLES        2     SINGLE VARIABLES        43
NON ZERO ELEMENTS        176     DISCRETE VARIABLES      42

GENERATION TIME      =        0.990 SECONDS

EXECUTION TIME       =        1.810 SECONDS        VERID MW2-25-069
```

```
GAMS 2.25.069  386/486 DOS                          05/13/94 14:14:09  PAGE     13
TOTAL FORCE RESOURCE ALLOCATION MODEL
Solution Report      SOLVE TFRAM USING MIP FROM LINE 215


               S O L V E      S U M M A R Y

     MODEL   TFRAM                OBJECTIVE  TFPOT
     TYPE    MIP                  DIRECTION  MAXIMIZE
     SOLVER  OSL                  FROM LINE  215

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      8 INTEGER SOLUTION
**** OBJECTIVE VALUE                33.6210

 RESOURCE USAGE, LIMIT          25.148     1000.000
 ITERATION COUNT, LIMIT         517        1000

 OSL Release 2,  GAMS Link level 3  ---  386/486 DPMI  1.3.045-020


 Work space allocated                --      .21 Mb


 Relaxed optimum objective value:      33.845226
 Bound on best integer solution:       33.828862
 Objective value of this solution:     33.621000

 Relative gap: .00614 Absolute gap:    .20786248
 Optcr        : .01000 Optca:          .50000000

 The solution satisfies the termination tolerances

                          LOWER      LEVEL      UPPER     MARGINAL

---- EQU COMBAT              .          .          .        -1.000
---- EQU AHDREQ            4.000      4.000      +INF        .
---- EQU AMDREQ            4.000      4.333      +INF        .
---- EQU CBGREQ           12.000     12.000      +INF        .
---- EQU MWREQ            27.000     27.000      +INF        .
---- EQU RIEWREQ           2.000      2.000      +INF       -0.241
---- EQU ASWREQ           16.000     16.000      +INF        .
---- EQU ASAWREQ           6.000      6.000      +INF        .
---- EQU ASWARAT           0.400      0.600      +INF        .
---- EQU ASWRRAT           0.400      6.000      +INF        .
---- EQU MEFREQ            6.000     11.000      +INF        .
---- EQU RHDREQ            4.000      4.000      +INF        .
---- EQU ARMYBUD          -INF    74886.250  75000.000      .
---- EQU AFBUD            -INF    77069.250  77500.000      .
---- EQU NAVYBUD          -INF    84981.500  85000.000      .
---- EQU RMDREQ            4.000      4.333      +INF        .
---- EQU TAAD             -INF        8.000     12.000      .
---- EQU TBG              -INF        7.000     15.000      .
---- EQU TAWREQ           -INF       24.000     24.000       0.286
---- EQU FDAWREQ          20.000     20.000      +INF        .

  COMBAT      Total combat potential of MCP's in force
  AHDREQ      Operational Requirements for Active Heavy Divisions
```

AMDREQ	Operational Requirements for Active Medium Divisions
CBGREQ	Operational Requirements for Surface or Carrier Battle Groups
MWREQ	Operational Requirements for Mine Warfare Ships
RIEWREQ	Operational Requirements for RIEW assets
ASWREQ	Operational Requirements for ASW assets
ASAWREQ	Operational Requirements for active ASW assets
ASWARAT	Require at least 40% of all Active ASW is Fixed Wing
ASWRRAT	Require at least 40% of all Reserve ASW is Fixed Wing
MEFREQ	Operational Requirements for Marine Expeditionary Forces
RHDREQ	Operational Requirements for Reserve Heavy Divisions
ARMYBUD	Budget Authority for Army Forces
AFBUD	Budget Authority for Air Force Service
NAVYBUD	Budget Authority for Naval Forces
RMDREQ	Operational Requirements for Reserve Medium Divisions
TAAD	Political Requirements for no more than 12 Active Army Divisions
TBG	Political Requirements for no more than 15 Carrier Battle Groups
TAWREQ	Political Requirements for no more than 24 Forward Dep and Heavy Wings
FDAWREQ	Operational Requirements for Forward Deployable Aircraft Wings

---- VAR X Number of Mission Capabilities Packages required in force

	LOWER	LEVEL	UPPER	MARGINAL
ADA	1.000	1.000	10.000	0.340
LIDA	2.000	2.000	10.000	0.548
ACRA	.	.	10.000	0.623
MEFA	3.000	3.000	10.000	0.414
AADA	1.000	1.000	10.000	0.307
SIBA	.	4.000	10.000	0.338
LIDR	.	.	10.000	0.230
ACRR	.	10.000	10.000	0.532
MEFR	.	8.000	10.000	0.371
SIBR	.	3.000	10.000	0.257
HDA	.	4.000	10.000	1.000
SHBA	.	.	10.000	0.435
HDR	.	4.000	10.000	0.738
SHBR	.	.	10.000	0.322
CBG	6.000	6.000	10.000	0.401
FDA	10.000	17.000	30.000	EPS
SAGA	.	6.000	10.000	0.199
FDR	.	3.000	10.000	EPS
SAGR	.	6.000	10.000	0.199
CTBG	1.000	1.000	10.000	0.401
CD	1.000	1.000	10.000	0.145
SOFNA	6.000	6.000	20.000	0.030
SOFA	1.000	1.000	10.000	0.030
RBA	1.000	1.000	10.000	0.049
SOFNR	6.000	8.000	10.000	0.020
SOF	4.000	8.000	20.000	0.020
ASA	40.000	40.000	60.000	0.014
HBA	2.000	2.000	10.000	-0.018

VAR X Number of Mission Capabilities Packages required in force

	LOWER	LEVEL	UPPER	MARGINAL
RIEWA	1.000	1.000	10.000	EPS
RIEWR	.	1.000	10.000	EPS
MWA	6.000	17.000	40.000	0.010
MWR	.	10.000	10.000	0.010
ASWFA	.	3.000	10.000	0.004
ASWRA	.	3.000	10.000	0.004
ASWFR	.	10.000	10.000	0.004
ASWRR	.	.	10.000	0.004
USACE	1.000	1.000	10.000	0.001
USCG	1.000	1.000	10.000	0.001
ICBMW	1.000	1.000	10.000	0.001
IA	1.000	1.000	10.000	0.001
DODSC	1.000	1.000	10.000	0.001
DODSS	1.000	1.000	10.000	0.001

	LOWER	LEVEL	UPPER	MARGINAL
---- VAR TFPOT	-INF	33.621		

TFPOT Total force combat potential

**** REPORT SUMMARY : 0 NONOPT
0 INFEASIBLE
0 UNBOUNDED

```
----    229 PARAMETER REPORT1             =   236937.000 Total Cost of the
                                                         Proposed Force
                                                         Structure
            PARAMETER REPORT2             =       33.621 Total Combat Power
                                                         of the Proposed
                                                         Force Structure
            PARAMETER REPORT3             =       14.920 Total
                                                         Non-Warfighting
                                                         Potential of the
                                                         Proposed Force
                                                         Structure

EXECUTION TIME       =        0.720 SECONDS      VERID MW2-25-069

USER: Dr. John Farr                                  B940429-1026Ax-MW2
      Dept. of Systems Engineering, U.S. Military Academy

**** FILE SUMMARY

INPUT      C:\FORCAM\TFRAM.GMS
OUTPUT     C:\GAMS\TFRAM.LST
```